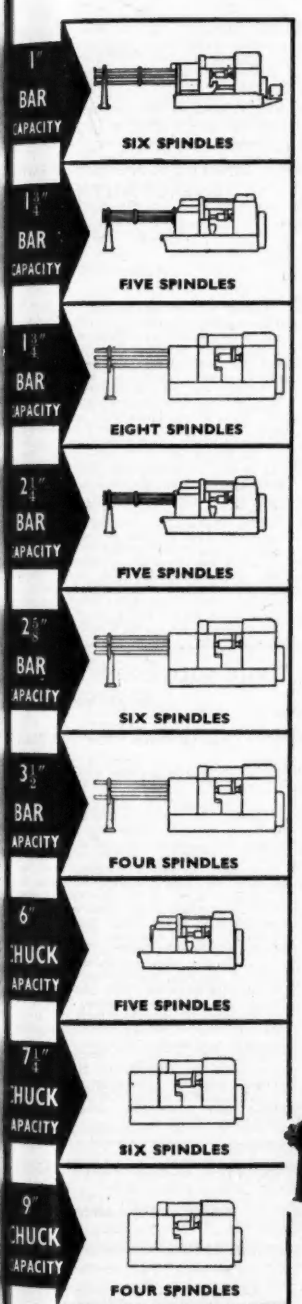
Wickman

MULTI-SPINDLE AUTOMATICS

In a range from the super-fast 1" — 6 Bar Machine to the big robust 9" — 4 Chucking Machines.

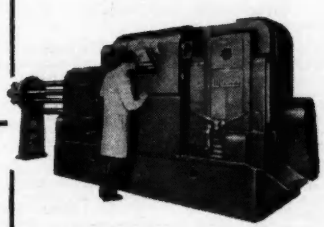


The solution to a repetition machining problem frequently depends upon the selection of a machine that's ideal for size, power, and speed—in short, just right for the job.

In the Wickman range the choice is wide and easy; from the fast 1"—Six Spindle Bar Machine, an exceptionally versatile automatic which can be supplied with bar feeding in two stations and spindle stopping if required, to the recently introduced 7¼"—Six Spindle and 9"—Four Spindle Chucking Automatics which offer new opportunities for fast, accurate, and economical machining of castings, forgings, billets and pressings, etc.

All machines in the range incorporate the patented Wickman Autosetting Mechanism by which all tool strokes can be set merely by the adjustment of a lever, without cam changing.

Inherently accurate, trouble-free, and easy to service, and backed by the experience and advice of Wickman tooling and engineering specialists, this range of automatics provides a ready answer to the universal need for higher output and lower costs.



2¾"—6 Spindle Automatic

WICKMAN LIMITED

MACHINE TOOL DIVISION, BANNER LANE, COVENTRY

Telephone: Coventry 66271

364 WM.

THE ENGINEER

ESTABLISHED 1856

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NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

SUBSCRIPTIONS

U.K. & ABROAD £5. 10. 0. CANADA £5. 5. 0. annually including postage. Every subscriber is entitled to one FREE copy of the BUYERS GUIDE as published —extra copies 5s. each post free.

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

MONMOUTHSHIRE EDUCATION COMMITTEE

THE TECHNICAL COLLEGE OF MONMOUTHSHIRE, CRUMLIN

Dr. T. V. STARKEY, Principal

LECTURER IN ELECTRICAL ENGINEERING

A LECTURER IN ELECTRICAL ENGINEERING is required at the above College as soon as possible. Candidates must possess a Degree or equivalent qualification in Electrical Engineering, and have had wide industrial experience. Research and teaching experience would be regarded as added qualifications. The salary will be in accordance with the scale £965 by £25 to £1065 per annum.

Further particulars and forms of application can be obtained from the undersigned, to whom completed forms should be returned not later than 31st December, 1954.

C. E. GITTINS,
Director of Education.

County Hall,
Newport, Mon. E7128

COLLEGE OF TECHNOLOGY, BIRMINGHAM

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

SENIOR LECTURER IN THE MECHANICAL ENGINEERING SECTION

Applications are invited for the post of SENIOR LECTURER in the MECHANICAL ENGINEERING SECTION of the Department. Candidates should have an Honours Degree or equivalent qualification including the subject of Mechanics of Fluids or Hydraulics. Teaching experience is essential, and some industrial and research experience are desirable. Salary in accordance with the Burnham (Further Education) Scale (Men), £1065–£25–£1215.

Further particulars and form of application may be obtained from the Registrar, College of Technology, Suffolk Street, Birmingham, 1. Completed forms should be returned not later than two weeks after the appearance of this advertisement.

K. R. PILLING,
E7118 Clerk to the Governing Body.

ELECTRICAL ENGINEERS (DISTRIBUTION)

CENTRAL ELECTRICITY BOARD, MALAYA

ELECTRICAL ENGINEERS (DISTRIBUTION) required by the Central Electricity Board, Malaya. Salary scale (including expatriation pay and present temporary allowance at rate for single men) equivalent to £1197, rising to £2100 a year. Commencing salary according to qualifications and experience. Additional temporary allowances totalling £210/£399 a year (married men), and £301/£630 (family men). Option of appointment either (a) on agreement for three years with prospect of permanency, or (b) on contract for three years with gratuity of £200/£280 a year. Opportunity of terminating appointment after one year's service. Free passages, liberal leave on full salary. Candidates must have had sound training in both electrical and mechanical engineering with experience in the operation of medium electricity supply undertakings and possess a competent knowledge of the maintenance of high and low-tension overhead and underground A.C. distribution systems and substation plant. They should preferably be Corporate Members or Graduates of the Institution of Electrical Engineers or possess degrees or other qualifications carrying exemption from the Institution's Graduate Examination.—Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience, and quote M2A/40440/EH. E7120

MINISTRY OF SUPPLY

OVERLEY HILL, SALOP

ENGINEER

Ministry of Supply requires ENGINEER at Overley Hill, Salop, or Birmingham (optional) as GAUGE OFFICER for the area and to control metrological work at the station. British of British parents. Recognised engineering apprenticeship and A.M.I.C.E., or Mech.E., or E.E., or exempting qualifications. Sound knowledge of engineering metrology applied to the examination of gauges and testing of measuring instruments and experience of gauge manufacture are essential. Salary: within £620 (age 25) to £960, plus a pay supplement of from £25–£35 p.a. Slightly more at Birmingham. Not established but opportunities to compete for establishment may arise. Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting C861/54A. Closing date 8th January, 1955. E7121

LONDON COUNTY COUNCIL

CIVIL ENGINEERS, CIVIL ENGINEERING ASSISTANTS AND DRAWING-OFFICE STAFF

CIVIL ENGINEERS, CIVIL ENGINEERING ASSISTANTS, and DRAWING-OFFICE STAFF, for design of large civil engineering works in connection with main drainage and sewage purification. Salaries within range £300–£892.—Application form (returnable within 14 days) from Chief Engineer (54/65), London County Council, County Hall, S.E.1. (S.A.E.) (1544.) E7123

PUBLIC APPOINTMENTS

BRITISH ELECTRICITY AUTHORITY

LONDON DIVISION

APPOINTMENTS

Applications are invited for the following superannuable posts. Conditions of service in accordance with N.J.B. Agreement, Schedule C. Salary includes London allowance. Qualifications entitling to Graduate Membership of the I.E.E. or I.Mech.E. an advantage.

SENIOR AND ENGINEERING DRAUGHTSMAN (ELECTRICAL ENGINEERING)
Vacancy No. 54/1069

Experience in preparation of engineering drawings associated with design, layout and construction of the electrical plant in a modern generating station, including the following :—H.T. and auxiliary switchgear, generator transformers, motors and starters, associated diagrams, cable schedules, &c.

SENIOR AND ENGINEERING DRAUGHTSMAN (CIVIL, STRUCTURAL AND ARCHITECTURAL)
Vacancy No. 54/1070

Experience in the preparation of working drawings required in the construction of modern generating station in either of the following sections :—(a) Design and details of reinforced concrete for main foundations, buildings, road, river works, &c.; (b) design and details of heavy structural steelwork for main buildings, &c.

Salary: Senior, Grade 4, £787 10s./£892 10s. p.a., or Grade 5, £672/£777 p.a. Engineering, Grade 6, £535 10s./£661 10s. p.a.

Applications, quoting vacancy number, may be made on form obtainable from Divisional Secretary, British Electricity Authority, London Division, P.O. Box 136, Generation House, Great Portland Street, W.1, and be received within 14 days of this advertisement. E7115

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

BRACKNELL, BERKSHIRE

ENGINEER

United Kingdom Atomic Energy Authority requires an ENGINEER to assist a senior engineer in the management of a general engineering workshop at Bracknell, Berkshire. He will be responsible for the day-to-day control of the production of a wide range of scientific apparatus and engineering plant required in a research establishment. Applicants should have served a recognised apprenticeship and be either Corporate Members of one of the senior engineering institutions or have equivalent qualifications in the field of production engineering. They should have a wide knowledge of workshop practice as applied to the making of plant and apparatus of the "one off" variety, and have had control of skilled and semi-skilled mechanics. Experience in planning, progressing and cost control of manufacture would be an advantage. Salary will be assessed according to age, experience and qualifications within the scale £645 (linked to age 25)–£995 per annum. The successful candidate will be required to join the Authority's contributory superannuation scheme which is to be introduced in the near future, and salaries will be increased to cover personal contributions.—Applications should be made to the Establishment Officer, A.E.R.E., Harwell, Didcot, Berks, quoting reference 2/103/172. E7161

GOLD COAST LOCAL CIVIL SERVICE

DIRECTOR OF RURAL WATER DEVELOPMENT

Duties : administration and direction of Rural Water Development Department. The Director will be responsible to the Minister for the organisation of the Department and will be the Minister's adviser on professional and technical matters and will be required to assist the Minister in the formulation of policy concerning the Department.

Appointment on contract for three tours of 15 months each. Consolidated salary £2600 per annum, plus gratuity payable on satisfactory completion of contract at rate of £37 10s. for each completed period of 3 months' service. Free first-class passages, free medical attention for the officer, generous leave.

Candidates, who should be between 35–45 years of age, must be Corporate Members of the Institution of Civil Engineers. They should have at least 7 years' experience in design and operation of water supplies, plus considerable experience of the mechanical aspects, and of the construction and administration of a water supply organisation. A knowledge of hydrology and geology as applied to water would be an advantage.

Further particulars on written application to the Director of Recruitment, Colonial Office, Sanctuary Buildings, Great Smith Street, London, S.W.1, giving brief details of age, qualifications and experience. Please quote reference BCD/140/13/03/D4. E7167

LINCOLNSHIRE RIVER BOARD

SURVEYOR/DRAUGHTSMEN

Applications are invited for the appointment of two SURVEYOR/DRAUGHTSMEN, at a salary in accordance with the following scale :—£540 per annum by £20 to £580 per annum, for duty in the office of the Engineer of the Board at Boston. The appointments will be subject to the provisions of the Local Government Superannuation Acts and to one month's notice on either side. The persons appointed will be required to use their own cars in connection with their duties and an essential user's allowance will be paid by the Board.

Applications, giving full details of the applicant's education, qualifications and experience, together with the names of two referees, should be submitted to the undersigned not later than 10th January, 1955.

G. E. PHILLIPPO,
Clerk of the Board.

50, Wide Bargate,
Boston, Lincs. E7126

PUBLIC APPOINTMENTS

MINISTRY OF SUPPLY

ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

MECHANICAL ENGINEERS

MECHANICAL ENGINEERS required by Ministry of Supply at Armament Research and Development Establishment near Sevenoaks, Kent ; Fighting Vehicles Research and Development Establishment near Chertsey, Surrey ; National Gas Turbine Establishment near Farnborough, Hants ; Aeroplane and Armament Establishment, Amesbury, Wilts ; Royal Aircraft Establishment, Farnborough, Hants, and outstations. Work concerned with research, design and development of a wide range of civil and military equipment, including aircraft, armaments, fighting vehicles, gas turbines, guided weapons, rockets and accessories. Appointments according to qualifications, age and experience connected with appropriate research or development. Scientific Officers (1st or 2nd-class Hons. Graduates). Salary, £445–£815 ; Experimental Officers and Assistant Experimental Officers (Higher School Certificate (Science) or equivalent—Degree or H.N.C. may be an advantage). Salary E.O. (Min. age 26), £690–£850 ; A.E.O. £276 (age 18) to £615. Women somewhat less. F.S.S.U. benefits may be available for S.O. class. Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting C805/54A. E6964

BOROUGH OF SHREWSBURY

WATER DEPARTMENT

APPOINTMENT OF AN ASSISTANT ENGINEER

Applications are invited from suitably qualified candidates with at least two years' practical experience in water supply for this post, the duties of which may include works in connection with the design and construction of aqueducts, service reservoirs, treatment works, &c., and normal maintenance. The salary, which will depend on qualifications and experience, will be within the new A.P.T. Grade III of the National scales (£600–£725 per annum).

Housing accommodation will be provided if required.

The appointment is permanent and is subject to the provisions of the Local Government Superannuation Acts, 1937–1953, and to a satisfactory medical examination.

Applications, stating age, qualifications and details of experience, together with the names of three persons to whom reference may be made, should be submitted to Mr. J. H. Sabido, B.Sc., A.M.I.C.E. M.I.W.E., Engineer and Manager, Water Department, Shelton, Shrewsbury, so as to be received not later than the 31st December, 1954.

S. R. H. LOXTON,
Town Clerk.

Guildhall,
Shrewsbury. E7019

ST. PANCRAS BOROUGH COUNCIL

BOROUGH ENGINEER'S DEPARTMENT

TECHNICAL ASSISTANT AND JUNIOR ASSISTANTS

Applications invited for following appointments in Borough Engineer's Department :—

(a) TECHNICAL ASSISTANT. New A.P.T. Grades I–II (£500–£640). Commencing salary according to qualifications and experience. Preference to candidates having passed Inter. Exam. of I.M.E. or parts of Exam. of I.C.E.

(b) TWO JUNIOR ASSISTANTS (one permanent and one temporary) in drawing-office. Higher General Division (£275–£475), according to age, &c. Applicants should have completed National Service and be neat and expeditious draughtsmen with drawing-office experience.

London weighting allowance according to age. No housing. Applications and names of three referees by 31st December.

R. C. E. AUSTIN,
Town Clerk.

St. Pancras Town Hall,
Euston Road, London, N.W.1. E7111

BRITISH WELDING RESEARCH ASSOCIATION

GRADUATE ENGINEERS

Fatigue investigations, testing and stress analysis of welded structures. The British Welding Research Association requires GRADUATE ENGINEERS to join research teams working on these projects. Honours Engineering Degree essential, knowledge of engineering research practice and materials testing an advantage. Positions available in Research Officer (£450–£800 p.a.) and Senior Research Officer (£700–£1150 p.a.) grades, qualifying for membership of superannuation scheme (F.S.S.U.).—Written applications to Chief Administration Officer, B.W.R.A. Research Station, Abington Hall, Abington, Cambs. E1273

LONDON COUNTY COUNCIL

CIVIL AND STRUCTURAL ENGINEERING ASSISTANTS

CIVIL and STRUCTURAL ENGINEERING ASSISTANTS for design and detailing of engineering structures in concrete and steel. Salaries within ranges £300–£556, £561–£739. Also TRACERS.—Application form (returnable within 14 days) from Chief Engineer (54/66), London County Council, County Hall, S.E.1 (S.A.E.) (1545) E6892

PUBLIC APPOINTMENTS

HER MAJESTY'S OVERSEA CIV SERVICE

FEDERAL GOVERNMENT OF NIG

MECHANICAL ENGINEER, PUBLIC WORKS DEPARTMENT

Duties include the supervision and control maintenance and repairs of mechanical engi plant required for the construction and maint of urban water supplies, including pumps of all earth-moving plant and vehicles.

The appointment is pensionable on pro in the salary scale £910 to £1560 per annum, of entry determined by war service and profe experience. Free first-class passages for the and his wife, and an annual maintenance all of up to £75 each is payable in respect of two under 18 years of age. Furnished quarters pr if available, at low rentals. Leave is granted rate of seven days for each completed mo resident service.

Candidates should either have an Engi Degree, giving exemption from Sections A of the examinations of the Institution of Me Engineers with two years' post-graduate mec engineering experience, or have passed or Diploma giving exemption from Sections A of the examination of the Institution of Me Engineers or Institution of Civil Engineers (m anical subjects), and have had at least five mechanical engineering experience, in workshop on engineering construction plant and vehicles.

Candidates should apply in writing to the D of Recruitment, Colonial Office, Sanctuary Bu Great Smith Street, London, S.W.1, stating age, qualifications and experience, and quotin ence No. BCD. 112/409/04.

UNITED KINGDOM ATOMI ENERGY AUTHORITY

ALDERMASTON

TECHNICIANS

United Kingdom Atomic Energy Au Aldermaston, requires TECHNICIANS to the Industrial Safety Officer with the surv of temporary electrical installations in labo and all aspects of safe working in laboratori shops, general mechanical engineering wo and allied services with a view to advising implementation of standard codes of prac the development of new ones as necessary. dates should have served a recognised me or electrical engineering apprenticeship and an associated technical qualification, prefe the H.N.C. level. A wide background of and supervisory experience, together with an in safety problems is essential. Salary, £66 30) to £772 per annum. The successful a will be required to join the Authority's superannuation scheme to be introduced and the salary scale quoted above will be a to cover contributions. Housing accomm will be available within a reasonable pe married officers who live outside the radiu Establishment's transport facilities.—Appl form from Senior Recruitment Officer, A. Aldermaston. Quote ref. 334/WGE/25.

THE GOLD COAST LOCAL C SERVICE

DEPARTMENT OF HOUSING

EXECUTIVE ENGINEER

Duties : to undertake structural design of building projects, including reinforced details and construction and maintenance drains and sewers. Maintenance of const plant and equipment. Responsible for control of funds for such projects in t Appointment would be on contract terms tour of 18–24 months. Gross emoluments mental scale £1130–£2020 per annum, su gratuity. Outfit allowance ; free passag medical attention. Generous leave.

Candidates, who should be between 21 years of age, must be a Chartered Municipal or hold the Testamur of the Institution of M Engineers and have experience of design an of buildings for housing estates and ancill or Chartered Civil Engineers with experi housing and housing administration.

Further details may be obtained on writ cation to the Director of Recruitment, Office, Sanctuary Buildings, Great Smit London, S.W.1, giving brief details of age, tions and experience. Please quote BCD/160/13/03/D4.

BRITISH ELECTRICITY AUTH

RESEARCH LABORATORIES

TWO GENERAL ASSISTANT ENG

Research Laboratories, British Electricity, Leatherhead, require TWO GE ASSISTANT ENGINEERS.

Candidates should have a University D equivalent qualifications in Electrical Engin in Physics. Duties include research on ele precipitation and allied problems at Leather Croydon Laboratories.

Salary N.J.B. Grade 4, £675–£850 p.a.

Applications, stating age, qualifications, and present position and salary, should be s to D. Moffat, Director of Establishments Street, London, W.1, by 17th January, 195 reference ENR./541.

THE ENGINEER

DECEMBER 24, 1954

European Coal and Steel Community

LAST Tuesday, the "agreement of association" between the United Kingdom and the European Coal and Steel Community was signed in London. The terms of the agreement have been set out in a White Paper published by H.M. Stationery Office. A statement issued after the signing explained that the agreement established a "Standing Council of Association" composed of four representatives of the United Kingdom Government and four representatives of the Community's High Authority. The function of this council would be to provide means for continuous consultation in regard to matters of mutual interest relating to coal and steel and, where appropriate, in regard to the co-ordination of action, consistent with the international obligations of the parties concerned, to deal with these matters. It was recognised, the statement continued, that the extent of the benefits to be obtained would inevitably depend upon the extent to which normal trade could flow between the United Kingdom and the Community. The Council of Association had therefore been given the duty of examining restrictions and other factors affecting mutual trade in coal and steel between the two areas, with a view to making such proposals for their reduction or elimination as might be agreed for the mutual benefit of the United Kingdom and the Community. The agreement also provides that matters which would normally be considered by the Council of Ministers or the Governments of the member states of the Community should be the subject of special meetings. At such meetings the United Kingdom Government would be represented, together with "persons discharging public responsibilities in regard to coal and steel in the United Kingdom."

Study Conference on the Human Problems of Industrial Communities

IN July last, the Duke of Edinburgh invited a number of industrialists and trades unionists to a meeting at Buckingham Palace to discuss the desirability of holding a Commonwealth and Empire conference on the human problems of industrial communities. It was then decided to hold such a conference at Oxford in July, 1956, and committees were appointed to deal with the preparation of a programme, study tours, finance, membership, &c. Last week a further meeting was held and the recommendations of the committees were discussed and a number of decisions in connection with the conference were made. The meeting decided to constitute itself an independent council for the sole purpose of sponsoring the conference and made itself responsible for the policy and finance. H.R.H. The Duke of Edinburgh was graciously pleased to accept the office of president of the conference, which will be called "H.R.H. The Duke of Edinburgh's Study Conference on the Human Problems of Industrial Communities within the Commonwealth and Empire." Sir Harold Hartley was appointed as chairman of the council and Sir John Hanbury-Williams as honorary treasurer. The conference will bring together men and women from the many countries of the Commonwealth and Empire with experience in the managerial, technical and operative roles in industry, and will give them the opportunity to find out how the various countries, some with advanced industrial development and others less advanced, can learn from and about one another. The conference will deal with human factors in industry which fall outside the normal machinery of industrial co-operation—such personal factors as work satisfaction, health and welfare schemes, and such social problems as industrialisation creates for the individual, his family and community. It was decided by the council that 280 men and women between the broad age limits of twenty-five and forty-five, should be invited to the conference, and of these about 190 will come from overseas and ninety from the United Kingdom. The conference will start at Oxford on July 9, 1956, when the president will deliver his opening address in the Sheldonian Theatre by invitation of the University. The next three days will be spent in Oxford, partly in plenary meetings hearing talks on the main objectives of the conference and partly in study group discussions. This period will also be a preparation for the study tours of industrial centres which are to occupy the next nine days.

London Traffic and the Speed Limit

IN a recent statement in the House of Commons on London's traffic problems, the Minister of Transport and Civil Aviation intimated that the 30 m.p.h. speed limit on roads of "traffic importance" might be reviewed. The Minister has now asked the London and Home Counties Traffic Advisory Committee to review the incidence of the 30 m.p.h. speed limit on the main routes in the London traffic area, with a view to the removal of inconsistencies, paying special regard to the effect of such speed limits on the flow of traffic into and out of London, and to the incidence of accidents on such roads. The Minister has also asked the committee to examine the case for introducing differential speed limits on main traffic routes in the London area, whether or not at present restricted, and to report its recommendations as to the policy to be adopted in future as to speed limits. To undertake this review, the London and Home Counties Traffic Advisory Committee has set up a special sub-committee under the chairmanship of Mr. A. Samuels. The sub-committee, it is stated, will hold its first meeting early in the New Year and will then announce the manner in which it desires to receive the views of interested bodies.

British Productivity Council

THE annual general meeting of the British Productivity Council was held in London last week. At this meeting Mr. Tom Williamson, the general secretary of the National Union of General and Municipal Workers, concluded his year of office as chairman of the Council. He has been succeeded by Sir Ewart Smith, technical director of Imperial Chemical Industries, and Mr. J. Crawford, general president of the National Union of Boot and Shoe Operatives, has been elected deputy chairman. Four members of the Council retired—Sir Cuthbert Clegg, Mr. A. G. Stewart, Sir William Lawther and Mr. Jack Tanner, and five new members were elected—Mr. G. Pollock, Q.C., Mr. W. T. Winterbottom, Mr. H. Collison, Mr. W. E. Jones, and Mr. R. Openshaw. The report states that there are now ninety-six Local Productivity Committees and Associations and it points out that in a growing number of instances, committees, once they are well-established, convert to Local Productivity Associations to enable them to broaden their basis of membership. Associations have been established in Birmingham, Coventry, Bristol, Slough, St. Albans and other centres. It is of interest to note that the Council's work study unit, which was set up to develop a more widespread appreciation of this important technique for raising productivity, has already made visits to L.P.C.s and other institutions in all parts of the country, and is heavily booked for months ahead. The Council is also engaged in the preparation of industrial films and pamphlets, and reports on progress in specific industries to support its general educational campaign.

Nuffield Foundation Report

THE ninth annual report of the Nuffield Foundation shows that in the eleven years since the foundation was established by Lord Nuffield in 1943 and endowed with shares to the value of £10,000,000, it has allocated grants totalling more than £5,000,000. In dealing with the subject of technology the latest report states that although it is widely recognised that this country needs the aid of science not only for the business of living but more urgently for the all-important business of making a living against sharpening competition, the most appropriate way of increasing the supply and use of scientists is differently debated. It goes on to say that the problem is perhaps not simply the shortage of scientists, but the more general shortage of able persons. In this country, traditionally, large numbers of those deemed at schools and universities to be the ablest have tended to think that the professions or public administration offer greater scope to those trained in the "humanities." The change which needs to be engineered is, therefore, at least in part, social. The report records the willingness of the foundation to take an interest in this subject—a readiness which extends to the equally hampering and serious shortage of teachers of science in schools.

River Boards' Association

IN its recently published year book for 1954 the River Boards' Association gives a review of its principal activities for the year. This review states that the most important matter with which the association was concerned in the past year was the consideration of the terms of reference of the Departmental Committee on Coastal Flooding, known as the Waverley Committee, and to place before it the views of the association. To ensure that the fullest possible consideration would be given to this matter representatives of East Coast Boards were co-opted and all member boards of the association were invited to submit representations. Eventually a series of memoranda setting out the views of the association were submitted to the Waverley Committee, the recommendations of which have yet to be considered. The book contains a number of interesting and useful articles on a variety of subjects. In one of these articles Mr. R. H. R. Davey, the vice-chairman of the Essex River Board, deals with the report of the Waverley Committee and discusses some of its recommendations. The basic causes of land drainage difficulties are dealt with in an article entitled "Cause and Effect," by Lieut.-Colonel E. T.-L. Baker; and this is followed by an article entitled "Land Drainage Without Tears," by Mr. N. Medrington, of the Lee Conservancy Catchment Board. The papers presented before the association and discussed by its members during the annual conference in May last, are also included in the book.

Glass-Fibre-Reinforced Plastics in the Chemical Industry

By FRANCIS F. JARAY, Dr.-Eng. (Vienna), M.I. Chem. E.

No. II—(*Concluded from page 842, December 17th*)

The problem of corrosion in the chemical industry is gradually getting more difficult. The emergence of new plastic materials which can be shaped easily has given rise to methods of construction of chemical equipment which are both simple and comparatively inexpensive. We are only now beginning to understand the problems connected with the use of these materials, and the methods of construction, after some very serious difficulties in the beginning. This article gives further details of materials and methods and notes on some successful applications.

Permanency of Results

It is an indisputable, though very regrettable fact that most figures given for the mechanical and chemical strength of laminated plastics only refer to new materials, fresh from the manufacturing process. Contact with water or other liquid chemicals, exposure to humid air for any length of time, as well as exposure to dry or wet heat will very materially reduce these values. It has been stated that exposure to boiling water will reduce the strength of laminated plastics by as much as 60 per cent if the glass fibres were only heat treated, and by "only" 35 per cent if the glass fibres had been

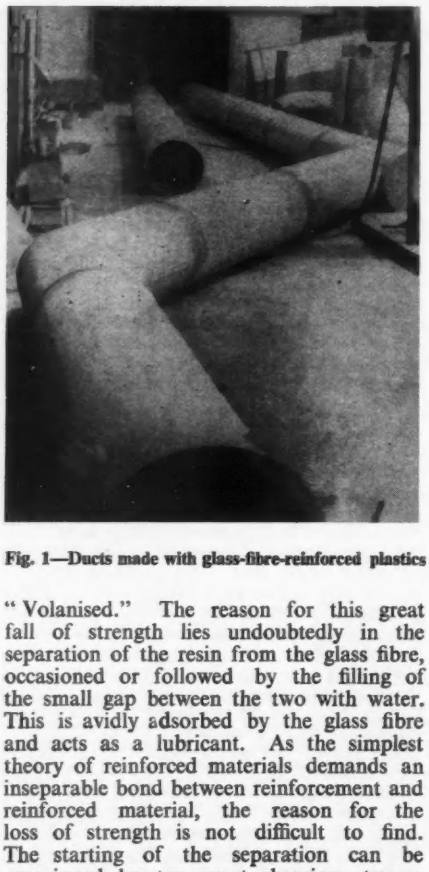

Fig. 1—Ducts made with glass-fibre-reinforced plastics

"Volanised." The reason for this great fall of strength lies undoubtedly in the separation of the resin from the glass fibre, occasioned or followed by the filling of the small gap between the two with water. This is avidly adsorbed by the glass fibre and acts as a lubricant. As the simplest theory of reinforced materials demands an inseparable bond between reinforcement and reinforced material, the reason for the loss of strength is not difficult to find. The starting of the separation can be occasioned by too great shearing stresses between the two heterogeneous materials, especially during the gelation and setting of the resin. Also, especially if glass fibre has not been properly treated to provide a good bond between glass and resin, water vapour may migrate through the resin (and no resin is proof against this as yet), or may have been sucked up by wick action, if the edges of the glass fibre laminates are exposed. This drop of strength will occur as long as there is no proper surface treatment available. The new vinyl-trichlorsilane is very promising indeed but no really long-term experiences are available. Experiences going over a few months which are the only ones available, mean nothing, unfortunately, and no final judgment can be passed before some considerable time has elapsed.

How serious wick action can be is best demonstrated by the description of a fairly large storage tank which, apart from superficial spalling, appeared to be perfect. However, the contents were seeping out at a not inconsiderable rate and it was assumed that they could find their way through the channels formed by the reinforcement which was not properly bonded to the resin.

Concerning the resistance of the resins which are used for the binding of the laminate, simple laboratory experiments will give only a faint indication of the suitability. As so often, they will only be able to indicate if a material is unsuitable, but even the best results in a laboratory will be by no means an indication that the material will perform properly under practical conditions. It is interesting to note in this connection that synthetic resin cements which are used for the bonding of brickwork will, due to the working conditions, give generally very much better performance than the resins themselves, and the resins in their turn will give much more satisfactory results than laminates made with them. The reasons for weight losses found in the laboratory on testing laminate samples have to be investigated very carefully in order to give any indication as to their importance and significance. If the same samples are also subjected to tensile strength tests, it will be found that a decrease of tensile strength does by no means go hand in hand with a change in weight.

All this does not mean in the least that there will be, and that there are, no uses for glass fibre laminated plastics in the chemical industry. It means, however, that extreme care must be taken at present in the choice of the uses, and that at the present state of knowledge and materials, exaggerated hopes should not be entertained and no superlative descriptions and promises be made. There is no doubt that with the further development of polyester and epoxide resins, and with more judicious use of furane resins, laminates will be made before very long which will fill the very badly felt want for a mechanically and chemically strong material which can be used at high temperatures.

At present descriptions of tanks and other equipment which are used at extreme conditions should be regarded as the exception rather than the rule. For each success story there are many more stories of failures. However, for the handling of crude oil which is mostly corrosive and contains large quantities of salt water, or for the handling of oil which contains a high proportion of paraffin, for the handling of plating solutions, provided that their temperatures are not in excess of 40 deg. Cent. or thereabouts and for similar problems the glass fibre laminates are already quite practical propositions. Similarly, silicone laminates are suitable for the handling of very oxidising liquids at ambient temperatures. Much more ambitious applications will one day be possible but at present extreme caution and a slow and methodical approach should be used. That the goal is capable of being attained within the next few years is clearly demonstrated by the fact that a large range of chemical apparatus is currently in use, manufactured from both phenolic and furane resins with mainly asbestos filler. These equipments resist their very often onerous chemical conditions but mechanically they are weak and therefore heavy, clumsy and expensive. It should certainly be possible to replace them using the same basic resin with the much more elegant method of glass fibre reinforcement.

Uses of Glass Fibre Laminates

It was mentioned before that the fabricator will have to make his decision in most cases taking into consideration the chemical resistance, the mechanical strength and the economics of each job. Very often mechanical strength for chemical construction is, though this may sound paradoxical, not of paramount importance. After all, most jobs could, structurally, be carried out

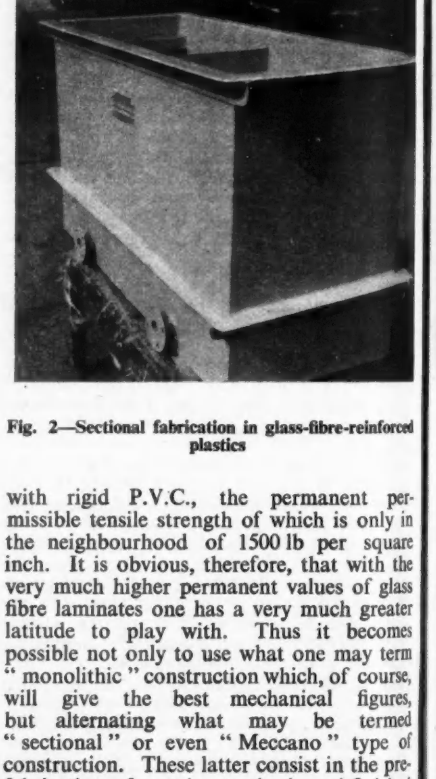

Fig. 2—Sectional fabrication in glass-fibre-reinforced plastics

with rigid P.V.C., the permanent permissible tensile strength of which is only in the neighbourhood of 1500 lb per square inch. It is obvious, therefore, that with the very much higher permanent values of glass fibre laminates one has a very much greater latitude to play with. Thus it becomes possible not only to use what one may term "monolithic" construction which, of course, will give the best mechanical figures, but alternating what may be termed "sectional" or even "Meccano" type of construction. These latter consist in the prefabrication of certain standard semi-finished products like sheets of ¼in thickness and angles, and constructing from these materials any jobs that may be required. If one goes so far as to stock or manufacture regularly certain diameter tubes one can, additionally, not only meet any requirement for ducting, but also for small cylindrical tanks.

Equipment required in the chemical industry and for which glass-fibre-reinforced plastics are, or may be, suitable can be classified under the following five headings:

(*a*) ducts, (*b*) tanks, (*c*) pipes and fittings, (*d*) extrusions, (*e*) special equipment.

Probably one of the easiest applications is in the ducts; chemical attack and temperature will never be too severe, for it is always possible to reduce it by aspiration of secondary air, and the chemicals are always in dilute form. It is also one of those applications which can be most easily made by the user himself from preshaped sheet and angle which he may keep in stock, using some resin as bonding agent. If he uses, additionally, some small quantities of glass cloth he can fix branches and connect fabricated sections with each other. Such constructions will, of course, be of square or rectangular cross-section, and bends and angles will be made by so-called lobster backing. It is quite clear that such ducts which have generally hardly any other mechanical duty but to keep themselves in position will not require a particularly high mechanical strength, and the sectional method should be quite adequate. However, in many cases, mechanical strength is indeed of some considerable importance, as for instance, in a case when a duct may be subject to heat stresses which cannot be relieved, or to vibration. Often, the duct itself may be intended to carry out some structural duties. In this case the ducting will have, of course, to be designed and fabricated in a proper manner to obtain the necessary strength figures. This can be obtained by wrapping glass cloth or glass fibre on suitable formers or mandrels, and impregnating them with a suitable resin. This can, if straightforward cylindrical or similar pieces or even simple bends are required, be done by wrapping strips of fibre mat or rovings or unidirectional cloth by hand or on a simple machine. The angle of the wrapping and the type of reinforcement used will determine the final strength of the article.

If complicated pieces like branches are required they can be manufactured by wrapping or laying up on formers which, when the resin impregnated glass fibre has set, are destroyed and removed. If many pieces of a complicated configuration are required it is often economically advantageous to cast the formers not from plaster, but from a low melting metal, which is then melted out. This method has the advantage of making the problem of a separating agent very much simpler, and if such jobs are done repeatedly the cost of material becomes negligible as the metal can be used over and over again. Even the simplest ducts, however, cannot be made in lengths exceeding 10ft or 15ft, as otherwise transport and handling become somewhat complicated. But it is quite easy to join pieces together by wrapping glass cloth over the joint and impregnating it with resin. On shrinkage the socket and joint thus produced will form an extraordinarily strong bond.

One method of making ducts and large-bore pipes should be mentioned in this connection. It is possible to make a rather fluid dough from resin with shopped glass fibres mixed into it, and then pour this into a mould of cylindrical shape, which is then rotated so that an even distribution of the reinforced resin mass is attained. If, at the same time, the mould is slightly heated, gelation and setting will occur fairly quickly, and the removal of the finished article from the mould will be very simple, as on following its tendency to shrink it will part itself from the mould. Fig. 1 shows some duct work of quite considerable diameter made by the Beetle Plastics Corporation, of the U.S.A. The above method of joining straight pieces together has been followed, and the method of lobster backing which has been followed

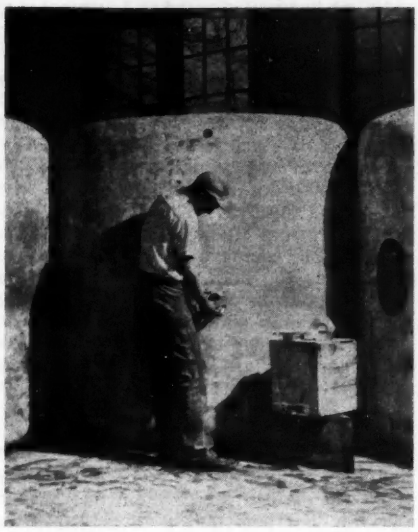

Fig. 3—1000-gallon capacity monolithic tanks, made from polyester resin reinforced with glass fibre mats

can clearly be seen. The strength of the material is amply demonstrated by the cleats shown in the foreground of Fig. 1, which are destined to take the whole load of the duct. In no other material than metal would it be possible to use such a thin and light construction for so considerable a duty.

Tank manufacture is, undoubtedly, the greatest field of application for laminate construction. Here, again, there are encountered monolithic construction, sectional construction and another form of construction which can be termed the permanent sectional one, i.e. the method by which tanks are assembled from prefabricated sections, but where the sections are bonded together in such a way as to allow future dismantling if necessary. Fig. 2 shows a small sectional fabrication by the Schori Division of the Ferro Corporation of America. The reinforcement by angles of the edges and also of the flat sides can clearly be seen, and it may be noted that all of these angles are of the same size, thus simplifying the problem of manufacturing and stock keeping. This is an electro-plating vessel which in service is

Fig. 4—Large single-piece glass-fibre-reinforced polyester tank for a road vehicle

exposed to comparatively mild chemicals at maximum temperatures of 40 deg. to 50 deg. Cent. Chemical resistance in this case is satisfactory and the loss of mechanical strength not so serious as to endanger the very robustly manufactured and reinforced polyester laminates. A similar type of construction, but made from ¼in thick furane resin bonded and carbon-filled glass fibre reinforced sheet and angles, is a hopper 5ft 6in by 4ft 10in deep, which has been developed by an American firm, the Electro Chemical Engineering and Manufacturing Corporation. This hopper is made from a material which, although particularly suitable for chemical resistance, has at present only a very indifferent mechanical performance. The hopper is used for storing chlorinated rubber (containing acidic solids, some dilute hydrochloric acid, chlorine gas) and, on occasion, alkaline soda ash. The first hopper of this type was installed in April, 1953, and has not shown any attack after more than a year's continuous use.

It is obvious that sectional construction will be limited in size by the strength of the available materials. However, even monolithic construction without special reinforcement is limited in size. If tanks have to be constructed of a greater size than can be made by more or less orthodox means, there are a number of methods by use of which these shortcomings can be overcome. The old method of lining mild steel tanks can be adapted to glass-fibre-reinforced plastic sheets. As the coefficient of thermal expansion of glass-fibre-reinforced plastics is not very much greater than that of steel, and as the material is mechanically very strong, there is every reason to assume that this method of construction will be successful, whereas the same method using other materials, like rigid P.V.C., has not been an unqualified success. Alternatively, of course, a fabricated shell can be inserted into a frame of mild steel sections and, if required, channels or sections of glass fibre laminates can be used to cover the frame members. In the technique of "lost shuttering" (which is quite common in the reinforced concrete field), the shuttering can be made from paper, cardboard, wood or metal. If complicated sections or shapes are called for, the shuttering can consist of a channel of light metal, the flanges of which are cut at regular intervals so that it can be bent and twisted into any required form.

Alternatively, a honeycomb structure can be used in which two plastic material skins are combined to form a sandwich with a lightweight material in between. This packing material can either be foam, preferably foamed *in situ*, or made from prefabricated honeycomb material. The danger of this type of construction lies in the fact that considerable attack can go on undetected till sudden collapse occurs if the inner skin is fractured.

If the idea of laminating is carried to its logical conclusion, one arrives at structures which have already proved their reliability in other plastic fields and applications.

In connection with the one-piece or monolithic tank construction, it is worth while to mention one of the early ambitious and, so far, very successful jobs. It was the fabrication of a number of 1000-gallon tanks for the Arabian-American Oil Company for carrying both water and fuel. The advantages of these tanks are their saving in weight, resistance to erosion followed by atmospheric corrosion to which metal tanks fall rapid victims in the desert, and the possibility of repairing accidental damage quickly,

cheaply, and without danger and heavy equipment. The tanks were essentially made in four parts, using a polyester resin. The fibre-glass mat was first cut to patterns to fit the contours of two male moulds. One mould served for the whole end, and the other one for half the shell. The moulds were made from wood, with a polished heavily coated wax surface. The mould was covered with a $\frac{1}{16}$in coat of polyester resin, followed by further layers of resin containing white filler, and covered with a number of layers of glass mat. The resin cured at room temperature, but did not in this way attain its full strength though it was strong enough to permit handling and fabrication.

After the manufacture of the two shell parts and the two ends their edges were trimmed, and the four parts fitted together, as

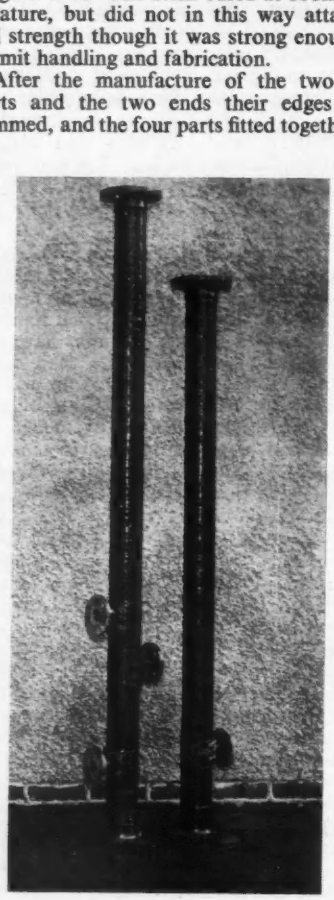

Fig. 5—4in bore glass-mat-reinforced plastic piping, 8ft and 7ft 6in long and complete with fittings

shown in Fig. 3. The gaps were then filled with resin, and fibre glass tape put over the joints both inside and out to obtain a good bond. When the joints had set the resin was finally cured by the injection of live steam into the tank. These tanks were made by the American Cyanamide Corporation.

A basically similar but somewhat more ambitious job was what is believed to be the first single-piece plastic milk tanker made from glass-fibre-reinforced polyester by the American Celanese Corporation. It has a capacity of 4000 American gallons, and is stated to be the largest one-piece tank moulding which has as yet been produced. The tank is approximately 27ft long and 58in in height, and the total weight is only 7000 lb, which is considerably less than a lined mild steel or stainless steel tank of similar dimensions. The tank was produced by the Marco method, which permits the introduction of resin between moulds by vacuum, pressure or a combination of both. This allows the production of a one-piece tank and in addition eliminates porosity. Unfortunately, the author has not been permitted to divulge further particulars of the method of fabrication, but some idea of the detailed method can be had from Fig. 4, which shows the tank being removed from the mould.

A method of making sectional circular tanks of 15ft diameter was described in *Modern Plastics* of May, 1952. The bottom of this tank which had a diameter of 15ft, consisted of ten sections made from $\frac{1}{4}$in thick glass-cloth-reinforced polyester resin and bolted together. The shell of the tank was made from 8ft high sections of similar design. The ceiling was made from similar sections as the floor, and a manhole was superimposed on one of the sections. The makers of this tank claim that from the same sections they can make two or three-tier tanks, i.e. tanks of 15ft diameter and 16ft and 24ft height. Though the strength of the individual sections is certainly very good as they have been made on a hydraulic press, the thickness leaves something to be desired, for not even a steel tank manufacturer will dare to use only $\frac{1}{4}$in thickness of steel for 24ft high tanks. These tanks are intended for the storage of crude oil for which polyester glass laminates are certainly eminently suitable, even if the oil is a sour crude and heavily contaminated with salt water.

The method of connecting the individual sections with each other was quite interesting. The edges of the sheet were thickened by additional layers of glass fibre laminate and a space between the two layers cored out to take the heads of a row of bolts. The remaining part of the gap was filled with resin and in this way the bolts were completely protected from the contents of the tank and no special materials had to be used. A similar method of protecting bolts has been developed in this country for aircraft purposes. A method without using bolts but using resin cement could easily be adapted for the construction of large tanks according to principles which have long since been recognised as economical in the reinforced concrete field.

The application of fittings to glass fibre laminate tanks is not always a simple matter. If the stress has to flow from a piece of metal to a piece of reinforced plastic, and if the two are connected by a row of bolts it will, due to the unequal behaviour of the two materials under stress, always be the first bolt which will transfer the major part of the total load with very unfortunate consequences. In the case of tanks, there can either be used metal fittings which bolt on to the glass fibre laminate in a manner which sandwiches the plastic between the two metal flanges, or the whole fitting can be produced from the reinforced plastic itself. As the stresses are so very much lower, this is a very much better solution of the problem.

When building tanks from one material, it is only logical that the connecting pipelines should be made from the same material and the first attempts to make glass-mat-reinforced polyester pipes were very promising. It is known that a pipe which is subject to internal pressure will have a hoop stress amounting to twice the longitudinal stress, and by using the reinforcement which can be rovings, mat or unidirectional weave in an appropriate manner, very efficient and economical pipes can be produced. It has also been found that putting the finished and not yet cured pipe under pressure by, say, wrapping wet Cellophane over it, the strength of the pipe is very considerably improved. This can be further improved by applying the reinforcement under stress and at the same time using a resin like the epoxide resins which show only very little shrinkage. In this way tubes can now be produced which are suitable for 1000 lb per square inch operating pressure and over, and which can be made to correspond to all the standard codes of practice. Connections of pipes with each other or with metal pipes can be made with standard flanges, loose flanges, stub-flanges and screwed joints; elbows, bends, "Y" pieces are, or will at least be shortly, available for any planned pipe installation. Fig. 5 shows two pieces of piping which have been made in this way.* It should be mentioned that whilst pipes are designed normally for internal pressure it is possible to vary the design and method of reinforcement so that external point or continuous loads can be accommodated.

In pipe making much depends on the type of mandrel round which the resin and reinforcement are applied. It has been found that, provided the mandrel is made from

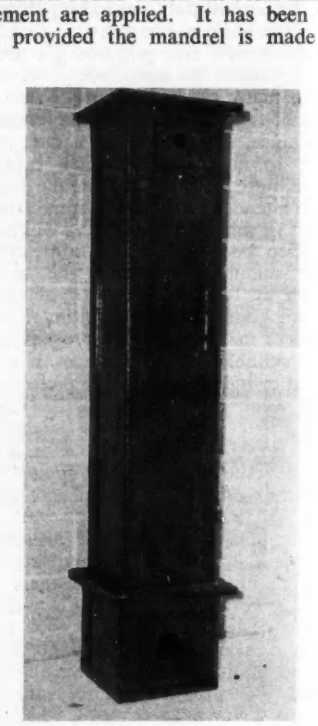

Fig. 6—Absorption tower used in acetate rayon manufacture, made of glass-cloth-reinforced carbon-filled furane resin

polished metal and is covered with a parting agent there is no difficulty in removing it. Split mandrels certainly make withdrawal easier, but a suitable mandrel design can easily increase the strength of the pipe and, at the same time, allow for a considerable saving in material.

Whilst polyester, epoxide and furane resins are generally used, silicones and P.T.F.E. can be used for making pipes, as considerable benefits can be obtained from a comparatively small increase in outlay for these more expensive resins. Although the field of application in the chemical industry for pipe installation is very great and glass-fibre-reinforced plastics should be able to fill many gaps which at present are often only filled unsatisfactorily with metal pipes, it will be wise to proceed gradually and not attempt to bring out too many designs at once. It will be better rather to develop one code of practice which can be followed and later standardised, than to try to comply with the many codes of practice intended for metal pipes. The manufacturers and users of rigid P.V.C. have already successfully taken this step.

No material of construction is complete

* James Mitchell and Sons (Greenock) Ltd.

and generally applicable if bolts and screws from the same material are not available. For this reason it is interesting to note that it is possible to extrude some of the binding materials and, at the same time, to fill them very highly with chopped glass strands. The material thus formed is quite satisfactory for the making of bolts and nuts. One machine is now available in America which extrudes shapes the reinforcing filaments of which are parallel to its axis. However, if only small quantities are required, rods and the like can be made from stretched bundles of rovings properly impregnated with resin. This may not be possible with large-scale production methods, but it gives the comparatively small quantities of rod required for the chemical construction field.

Only a very small attempt has been made to introduce glass-fibre-reinforced fabrics in the very large field of chemical equipment, which is capable of the greatest expansion in the future. Fig. 6 shows a small absorption tower measuring 1ft square by 6ft 3in high, made from carbon-filled and glass-fibre-reinforced furane resin by the Electro Chemical Engineering and Manufacturing Corporation of America. This tower has been in use for a long while without any damage or visible attack. It is used in a large acetate rayon factory and is fitted with packing plates with thirty-six 1in holes at 2in centres. A bubble tray 3ft 9½in diameter, made from the same material, handles hydrochloric acid and chlorinated solvents at a temperature of over 80 deg. Cent. Distributor trays for a tower handling hydrochloric acid and organic chlorides, and operating at 135 deg. Cent. have also been made from carbon-filled glass-fibre-reinforced furane resin.

The potential field into which the glass-fibre-reinforced plastics could certainly expand includes valves, pumps and fans, as well as large reaction towers, scrubbing towers, pickling and processing tanks, &c. However, whilst it is certain that developments will take place in these directions, progress must be slow and careful, as much has yet to be learnt about resins and methods of fabrication as well as the behaviour and performance of the finished plant. Much patient work will have to be completed before complicated problems can be faced with the same confidence as at present with metals.

Clarification of Surface-Water Sewerage Theory

By L. B. ESCRITT, A.M.I.C.E., F.R.San.I., F.I.San.E.

No. II—(*Concluded from page 837, December 17th*)

In 1906 D. E. Lloyd-Davies described a method by which the run-off from sewered areas could be related to rainfall statistics, and surface-water and combined sewers could be designed without recourse to primitive rules of thumb. Some twenty-five years later modifications of the Lloyd-Davies method had been found necessary to allow for the shape of the catchment area or irregularity of distribution on impervious area. Then a number of new methods were devised, based on differing assumptions, and a lively controversy arose. To-day there is still incomplete agreement as to the methods which should be used or the basic assumptions to be accepted. There are also many misconceptions due to lack of knowledge of how the rainfall data were obtained and other causes. In particular, there is a not uncommon belief that the methods in use do not make due allowance for storage in sewerage systems. Here it is attempted to show how the differences of opinion arose, to clarify theory and to demonstrate how the effects of storage in sewers and tanks can be calculated.

Allowance for Shape of Catchment

PROVIDED that the impervious area has been estimated correctly, the Lloyd-Davies method is sufficiently accurate for the design of estate drainage, or in all instances in which the catchment area is more or less rectangular and impermeability regularly distributed. But should the catchment consist of one or more large or dense areas coming before, following, or being separated by narrow or sparsely developed areas, the run-off due to a short storm of high intensity falling on part only of the total catchment can be greater than that due to a less intense storm of longer duration falling on the whole. In the design of large schemes, or when dealing with obviously irregular areas, it thus becomes necessary to find a method of determining the "effective time of concentration" and "effective impervious area."

Inspection of the drainage area plan can give a misleading impression of the degree of irregularity of shape or density of the impervious area, because the plan shows linear dimensions, not dimensions in time, and does not indicate percentage impermeability. The method by which the shape of the catchment can be demonstrated is to draw a graph known as the "time-area graph," which shows the total impervious area contributing at any time to the point at which run-off is desired to be known. The method of construction of the time-area graph is well known and will not be described here.

Inspection of the time-area graph gives some impression of the degree of irregularity of the impervious area, but other means are needed for translating this into an adjustment of the rate of flow, or, in other words, a means of finding the effective time of concentration and effective impervious area, as against the gross time of concentration and gross impervious area.

The first method for doing this was devised by John Reid[8] and was called the "tangent method." In its original form, however, it was erroneous in that it did not make any allowance for the effect of concavity of the lower end of the time-area graph, because Reid drew his tangent from a point at "minus Y minutes" from the origin of the curve instead of from the point of maximum concavity. This was pointed out by D. Wearing Riley,[9] to whom must be given the credit for the method as correctly used.

The tangent method is applicable to all rainfall formulas of the type $R=\frac{X}{t+Y}$. Its correct application can be explained more or less as follows.

If two parallel lines are drawn tangentially to the upper and lower sides of the time-area curve respectively and are spaced Y minutes apart in the direction of the time scale (provided that the abscissæ and ordinates are plotted to the same scales), the angle they form with the time axis indicates the run-off for that part of the time-area graph which falls between the two points of contact.

It will be seen that :

$$\tan\phi=\frac{Ap}{t_c+Y},$$

where

ϕ = the angle between the time axis and the tangent.
Ap = the impervious area between the points of contact.
t_c = the time of concentration between the points of contact.

and therefore the run-off in cubic feet per minute equals $60\cdot5\times X\times\tan\phi$. It is necessary to find by trial the largest value of ϕ possible in the circumstances to determine the maximum run-off.

It must be stressed that Wearing Riley's form of the tangent method is the only correct one. Nevertheless, Reid's original method continued to be used long after it had been disproved, and even in "Civil Engineering Code of Practice No. 5 (1950) Drainage (Sewerage)" this unsound calculation is still recommended for use.

As the tangent method is applicable only to rainfall formulas of the type $R=\frac{X}{t+Y}$, a new method[7] known as the "revised tangent method" was evolved for use with the formula $R=\frac{5\cdot9}{t^{\frac{5}{8}}}$. It is applied as follows.

A graph is drawn on tracing paper or tracing cloth with time of concentration as abscissæ and impervious area as ordinates. On this is plotted a series of curves of constant run-off in cubic feet per minute. The origin of this graph is placed on the origin of the time-area graph and, the axes of the two graphs being kept parallel, the origin is moved along the time-area curve from one end to the other. During this process the time-area curve cuts run-off curves of increasing value until a maximum is reached which is recorded as the maximum run-off for the area concerned.

The controversy that occurred during the early 1930s was started by the introduction by G. S. Coleman and A. Johnson[10] of a new method of surface water sewer design. Coleman and Johnson, in place of using rainfall statistics as compiled by Lloyd-Davies, Roseveare, Bilham, &c., supplied a "typical" local storm having a standard shape, in which intensity rose to a peak at about one-third of the duration from the commencement. In place of the Lloyd-Davies method they devised a tabular method by which the typical storm could be applied to the (tabulated) time-area graph and the maximum run-off found by summing the run-offs of the component parts of the curve.

There are objections to some of the opinions expressed in the Coleman and Johnson paper which were quite incompatible with the Lloyd-Davies theory. But Coleman and Johnson produced the first method by which the effect of any particular storm on any time-area graph could be esti-

Notation

Q_1—Rainfall run-off in cubic feet per minute.
Q_2—Discharge of sewer in cubic feet per minute.
Ap—Impervious area in acres.
R—Intensity of rainfall in inches per hour.
r—Inches of rainfall during T.
T—Duration of rainfall in hours.
t—Duration of rainfall in minutes.
t_c—Time of concentration in minutes.
N—Number of storms of this intensity occurring in ten years.
C—Storage capacity in cubic feet.
P—Outgo from storage in cubic feet per minute.
D—Diameter of sewer in inches.
L—Length of sewer in feet.
f—Fall of sewer in feet.

mated and on which were built the more satisfactory methods devised by Ormsby and Hart.

The concept of a typical storm is not irrational and, no doubt, given the data and the time to analyse them, it is within possibility for a series of typical storms to be found for all durations of rainfall likely to be wanted for sewerage calculations. But this has not been done, and without such analysed data the Coleman and Johnson method is of limited value. Moreover, for the method to receive general acceptance it would be necessary for the data to be made available, together with full particulars as to how the typical storms were derived. It would also be necessary to show that these storms were of equal frequency of occurrence. Furthermore, in practice, it would be necessary to apply, not merely one storm to the time-area graph, but also find which storm produces the maximum run-off. This approach has its appeal, but adequate data have not been analysed in such a manner as to carry the method to its logical conclusion and consequently the method has not been used in that way.

The Coleman and Johnson method will not be discussed any further for these reasons, and also because the method invented by Professor Ormsby[11] and improved by C. A. Hart[12] is a much more satisfactory procedure for finding the effect of a storm on an area of irregular shape.

In the Ormsby and Hart method a curve is plotted to the same time scale as the time-area graph (but in the opposite direction) to give total rainfall after beginning of storm. This is done on transparent cloth or paper so that the steepest part of the rainfall curve can be placed over the steepest part (generally) of the time-area curve. The time-area graph is then divided into intervals of time, each of which is dealt with as follows. During time t_n the amount of rainfall that falls is R_n. R_n/t_n, gives inches rainfall per minute, which can be converted to cubic feet per minute per acre and, multiplied by the increment of impervious area Ap_n over the same interval of time, gives cubic feet per minute for that part of the time-area graph. The sum of the run-offs of all the intervals into which the time-area graph is divided gives the total run-off from the whole of the area resulting from the storm.

For Coleman and Johnson's typical storm Ormsby substituted a "hypothetical storm," which, while somewhat similar in shape to the Coleman and Johnson storm, was plotted in such a manner that, between any times taken symmetrically about the point of maximum intensity, the amount of rainfall complied with the Ministry of Health standard curve.

The controversy of the early 1930s arose because the new methods gave different answers from the tangent method, yet the reason for the difference was not immediately evident. On the one hand, the tangent method could be proved by simple mathematics; on the other, Professor Ormsby wrote: ". . . the 'tangent' method . . . is based on the incorrect assumption that the discharge between any two points can be found by multiplying the intervening area by the average intensity during the corresponding time, and is necessarily misleading and incorrect. . . ."

It is found that if the original Lloyd-Davies method, the tangent method and the Ormsby and Hart method used with the hypothetical storm, are applied to a time-area graph which is a straight line, they all give the same answers. But when the time-area graph is not a straight line the tangent method gives a greater run-off (as expected) than the Lloyd-Davies method, and the Ormsby and Hart method gives a greater run-off than the tangent method.

There is, however, no mathematical error in either the tangent method or the Ormsby and Hart method. The difference in results lies in the assumptions as to rainfall. In the tangent method (including the revised tangent method) it is assumed that rain falls at a constant rate for the effective time of concentration and that there is no rain immediately preceding or following the design storm, which is not strictly true, as consideration of Bilham's method of obtaining rainfall data brings to light. Thus any variation of rainfall during the design storm not sufficiently great to cause a change in the effective time of concentration, and any moderate rainfall before or after the storm, could cause an increase of run-off above the amount calculated.

The Ormsby and Hart method is an accurate way of finding the run-off due to any storm of known intensity and shape. But the adoption of the hypothetical storm means the assumption that all "once-a-year" storms occur simultaneously—an assumption which is known to be untrue, although the extent of error is unknown. The result is that, whereas the tangent method tends to underestimate the run-off, the methods involving the hypothetical storm do the reverse. The truth lies somewhere between the two: but as the rainfall data necessary for finding the true answer have not been sorted out, the designer has to adopt one method or the other.

Which method is best remains a matter of opinion, but as the first is older, simpler and results in smaller diameter sewers, and as it has been used for many years without comebacks, it should appeal to the majority of engineers. The Ormsby and Hart method is of more value as a useful tool for research workers.

Storage

From time to time, it has been commented quite incorrectly that the Lloyd-Davies and the rational methods do not take storage into account, and that sewer sizes could be reduced if a method that allowed for storage could be devised. This not uncommon opinion is based on an erroneous belief that, because at the time of maximum run-off parts of the sewerage system are occupied by air, not sewage, this space could be occupied by sewage, and that this storage would lengthen the time of concentration and thereby permit the assumption of a storm of lower intensity.

As has already been mentioned, both adventitious storage and surcharge are ruled out of design by the practice recommended by the Ministry of Health, departmental committee, because these and other similar factors are required to cover storms less frequent and more intense than the design storm. If the sewer has all its storage and surcharge capacity taken up by the design storm, the storm allowed for must be increased in intensity, otherwise flooding will occur at frequent intervals. Such an approach is possible: sewers could be designed so that flooding occurred at certain low points, say, once during the thirty-year loan period. But such a method of design would be more difficult than that at present in use and, far from being economical, would in most instances result in the design of sewers to larger diameters.

Once the nature of storage in sewers is fully understood, this misconception is totally dispelled. But it is still held by many and this makes it necessary for the theory of storage to be fully explored.

The time of concentration of catchment areas is the time taken for the flow from the whole area to concentrate at the point of outgo. When the duration of storm equals the time of concentration, it is the delay between commencement of precipitation of rainfall and the moment when discharge at the point of outflow reaches its maximum. This delay is due to the storage in the sewerage system which results from the sewage being held back by frictional resistance to flow and, in normal sewer design, is that amount of storage that can occur without causing surcharge.

The amount of storage space available is therefore not the total void enclosed by the pipe: it is merely the space occupied by the sewage in the particular circumstances. It is the difference between the total rain precipitated and the total quantity discharged at the point of outfall. In the case of a system designed to the once-a-year storm, storage at end of storm and time of concentration (when $t=t_c$) is expressed by the formula:

$$C=178\cdot475\times Ap\times t_c^{\frac{1}{3}}.$$

The position can be explained by a simple parallel. A pint pot will hold a pint. If it is held at an angle, it will not hold a full pint because it will spill over first: in this it is similar to the sewerage system that floods above ground level before the storage capacities in its upper reaches are completely filled. If the bottom is knocked out of the pint pot it will hold no more than the thin stream of liquid that is being poured through it: its capacity is then determined not by its volume but by the volume of flow. If, however, the holder should place his hand under the pot so as to resist the leakage of the bottom, the quantity stored depends on the rate of flow and the resistance to leakage. A sewerage system is open at the bottom end: consequently the volume of water which it stores depends on the rate of flow and the resistance to discharge.

The storage space occupied can be increased by augmenting the resistance to outflow by either reducing the pipe size or increasing the rate of run-off. In either case, surcharge occurs. Storage can also be provided for in a tank or tank-sewer with controlled outlet.

Storage Formulas

The simplest practical storage problem is when the run-off from a catchment runs into the suction well of a pumping station from which water is pumped at a constant rate and time of concentration is zero or negligible. In such an instance, storms of high intensity but short duration will exceed the pumping rate by a great amount, but as the total quantity of run-off will not be great no great amount of storage capacity will be required. Similarly, storms of long duration but low intensity will not exceed the pumping rate by a great amount, if at all, and therefore again the storage capacity need not be large. Intermediately, there is one optimum storm which calls for the maximum storage capacity.

It can be found by differentiation that this capacity is expressed by the formula:—

$$C=\frac{4211Ap^{\frac{2}{3}}}{P^{\frac{2}{3}}}.$$

The rate of outgo P is the average rate and need not be constant throughout the period of the storm, provided that the variation is not so excessive as to cause a negative quantity of storage at any time, or to cause the maximum storage to occur before the end of the storm. The rate of precipitation may

also vary to some extent : consequently, the same amount of storage is required by the assumption of either a hypothetical storm of Professor Ormsby's type or a constant rate of precipitation over a limited period. It is found also that in the simple case of storage described, no matter what the rate of outgo, the storm that causes the maximum storage has an average rate of inflow that is 2·6 times the rate of outgo.

The next step is to find the effect of time of concentration when a sewerage system discharges to a storage well. It is then found that two formulas apply.

When the sewerage system discharges to the tank and the peak rate of discharge is not less than 2·6 times the average rate of outgo from the tank :

$$C=\frac{4211Ap^{\frac{1}{3}}}{P^{\frac{2}{3}}}-0\cdot625Pt_c.$$

When the peak rate of discharge from the sewerage system is less than 2·6 times the average rate of outgo from the tank is given, near enough for practical purposes, by the formula :

$$C=\frac{(Q_1-P)^2t_c}{Q_1}.$$

In the foregoing, Q_1 is the peak rate of run-off as calculated by the Lloyd-Davies method and t_c the time of concentration of the sewerage system. This last formula is the general formula for the condition $t_c=t$ or $Q=2\cdot6P$. There are conditions where Q is less than $2\cdot6P$. But as the use of the above formula never gives an error of more than 7 per cent and as it eliminates the need for very difficult calculations, its use as suggested is justified.

These formulas of recent derivation have been found useful for calculating the necessary storage capacities of suction wells of pumping stations, and of storage ponds or water meadows having controlled outlets. But they have several other possibilities—for example, the estimation of total discharge over storm overflow weirs.

When water is stored in a sewer from which it discharges freely, the rate of outgo rises from nil to maximum during the time of concentration and, therefore, it can be taken as averaging half the maximum rate of discharge and being half the average rate of precipitation during the same time. The constant 4211, therefore, has to be multiplied by

$$\frac{1\cdot3}{1\cdot6}\times\frac{2\cdot6^{\frac{2}{3}}}{2^{\frac{2}{3}}},$$

and the formula becomes :

$$C=\frac{4004Ap^{\frac{1}{3}}}{P^{\frac{2}{3}}}.$$

On the basis of this formula it becomes possible to design a single length of sewer of constant gradient and diameter by direct storage calculation without taking into account time of concentration or involving trial and error, as follows.

Because at the end of the time of concentration the bottom end of the sewer is running full, the top end just empty and intermediately the space occupied is directly in proportion to the distance from the top end, the storage in the sewer is given by the formula :

$$\frac{\pi D^2L}{144\times4\times2}$$

By equating this with the formula $\frac{4004Ap^{\frac{1}{3}}}{P^{\frac{2}{3}}}$ and substituting for P (which is half the maximum rate of flow Q_2) $\frac{3\cdot072D^{\frac{8}{3}}f^{\frac{1}{3}}}{2L^{\frac{1}{3}}}$ (from Crimp and Bruges's formula) the following formula is obtained:

$$D=\frac{48\cdot0767Ap^{\frac{1}{3}}}{L^{\frac{1}{8}}f^{\frac{1}{8}}}.$$

The accuracy of the foregoing calculations and reasoning can be checked by finding the required diameter of sewer in the ordinary way : or else obtaining the same formula for diameter of sewer by commencing with the Lloyd-Davies formula. As $t=t_c$ and $Q_1=Q_2$, by equating the Lloyd-Davies formula $Q_1=60\cdot5ApR$ with Crimp and Bruges's formula $Q_2=\frac{3\cdot072D^{\frac{8}{3}}f^{\frac{1}{3}}}{L^{\frac{1}{3}}}$, substituting $\frac{5\cdot9}{t^{\frac{1}{3}}}$ for R, and $\frac{L^{\frac{1}{3}}\pi D^2}{4\times144\times3\cdot072D^{\frac{8}{3}}f^{\frac{1}{3}}}$ for t_c the following formula is obtained:

$$D=\frac{48\cdot0767Ap^{\frac{1}{3}}}{L^{\frac{1}{8}}f^{\frac{1}{8}}},$$

which is the same as the formula obtained by the storage calculation.

By making a calculation for a simple case, it can be shown how surcharge can cause a marked increase of flow, but the accompanying additional storage affords little extra advantage.

If a length of sewer of constant gradient and diameter is fed throughout its length by an infinite number of equally spaced lateral connections and surcharged to such an extent that the total void of the sewer is just filled, the hydraulic gradient becomes a curve which is horizontal at the top end and at the bottom end is three times the gradient to which the pipe is laid. (In most practical cases the number of lateral connections is sufficient for the factor to be very nearly three.) As the surcharge produces a hydraulic gradient that is three times the gradient of the pipe, the discharge at the outgo is $\sqrt{3}$ times the discharge of the pipe running full.

In this condition, however, the storage capacity occupied is twice that when the bottom end of the pipe is just running full, and some additional advantage is therefore to be expected. The calculation then becomes :

$$\frac{Ap_2}{Ap_1}=2^{\frac{1}{3}}\times3^{\frac{1}{10}}=1\cdot895.$$

Thus, whereas the surcharge alone multiplies the impervious area that can be served by the factor 1·732, the surcharge, together with the accompanying storage, multiplies the impervious area by the factor 1·895—an advantage of less than 10 per cent over surcharge alone.

For the sake of brevity, the derivations of the storage formulas have not been given. But the calculations have been individually checked by methods differing from those on which the formulas were based, and are confirmed.

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Calculation of Losses in Transformer Cores

By A. LANGLEY MORRIS, M.I.E.E.

(*Concluded from page 839, December 17th*)

No. II—THE EFFECT OF HOLES IN THE CORE PLATES

The normal method of core loss calculation is based on the assumption of a uniform flux distribution throughout the core. Such a procedure can unwittingly lead to core constructional faults which cause higher losses and these increased losses can easily be ascribed to a poor batch of material or to faults arising during the building of the core. It is therefore desirable to have available a rigorous method of calculating the losses in transformer cores. Expressions are developed in this article which take account of the non-uniformity in the flux distribution across the face of the core plates. Non-uniformity can and does occur across the stack of the plates; one cause is the interleaving of the plates, but this third dimensional effect is not considered.

IN article No. I the losses were found for cores without holes or slots in the plates. Many transformer cores are bolted, while cores for large transformers are often provided with slots for cooling. Any hole or slot gives rise to extra losses by constricting the flux and by causing a non-uniform flux distribution.

Consider a stack of plates as shown in Fig. 8, the loss for the shaded portion is obviously :

$$W=P'\frac{L}{G} \quad . \quad . \quad . \quad . \quad . \quad (22)$$

where

$$P'=\frac{pqbwG^2}{1000} \quad . \quad . \quad . \quad . \quad (23)$$

Thus P' is a quantity similar to P in No. I of this article and represents the loss in a square stack G cm wide. The quantity L/G is therefore the geometrical reluctance of the shaded portion of Fig. 8.

If the stack has a slot or hole in the centre then the geometrical reluctance is increased and may be written $(L/G)+\Delta'$.

RECTANGULAR SLOTS

The loss for this case, which is the shaded portion shown in Fig. 9, would, if the flux were uniformly distributed, be :

$$W=P'\left\{\frac{L-D}{G}+\frac{D}{H}\right\} \quad . \quad . \quad . \quad (24)$$

Δ' being equal to $(D/H).(1-H/G)$. Because the flux is not uniform, the actual value of Δ' will be :

$$\Delta'=\frac{D}{H}\left\{1-\frac{H}{G}\right\}+\Delta_6 \quad . \quad . \quad . \quad (25)$$

Where Δ_6 should take account of the dimensions L, G, H and D. However, as already mentioned in No. I of this article, four dimensional variables are not suitable for numerical computation, so it is desirable to assume that one of them is much greater than the others. In the present instance

either the slot length D or the unslotted portion $(L-D)$ may be made large. Taking the former case first, which implies that the flux has become uniform along the centre line of the slot, then Fig. 10 gives the values

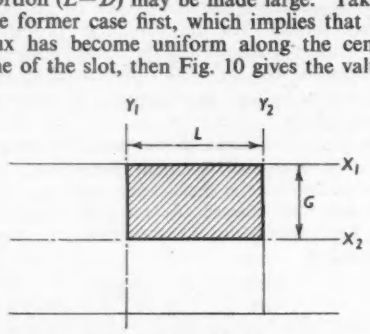


Fig. 8—Unslotted plate

of the correction factor. Δ_6, with G/H as the variable and $(L-D)/G$ as the parameter.

For the second alternative, i.e. $(L-D)$ large, the slot length $2D$ has two limits, infinity or zero. The first case is the same as the curve for $(L-D)/G=\infty$ in Fig. 10. This curve has been redrawn in Fig. 11 as $D/H=\infty$ (which is the same thing), together with the curve for $D/H=0$. From these two curves it can be seen that the value of Δ_6 does not depend very greatly upon the value of D/H. In order to see which of the two curves apply when D/H is reasonably small, a rigorous analysis involving elliptic functions was made for the ratio $D/H=0{\cdot}32$. The values for Δ_6 were found to coincide with the curve $D/H=\infty$. Thus the curves given in Fig. 10 should meet nearly all practical cases and their derivations are given in Appendices 6, 7 and 8.

Circular Holes

An approximate method of estimating the losses due to a circular hole is to make use of the results in the last section. The circular hole can be assumed to be equivalent to a square slot whose sides are 0·85 of the diameter. Such a square is the mean between the circumscribed and inscribed squares. For this assumption :

$$\Delta'=\frac{m^2}{1-m}+\Delta_6 \quad . \quad . \quad . \quad . \quad (26)$$

Where

$$m=0{\cdot}85\,.\,R/G,$$

and Δ_6 is given by Fig. 10 with $G/H=\dfrac{1}{1-m}$,

and

$$(L-D)/G=(L/G)-m,$$

with R=radius of hole situated as shown in Fig. 12.

Another solution can be found by means

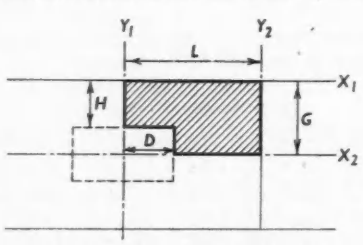


Fig. 9—Plate with rectangular slot

of a special form of Schwarz and Christoffel transformation. Details of this analysis are given in Appendix 9, from which it may be verified that :

$$\Delta'=\Delta_7,$$

Where Δ_7, expressed as a function of R/G, is given in Fig. 13.

A further solution has been given by Hague[10] who made use of cylindrical harmonics to find a solution of the Laplacian field.

Hague's expression, modified to conform with the arrangements in the present paper, is:

$$\Delta'=\frac{(G/L)+(L/G)}{(G^2/R^2)-1} \quad . \quad . \quad . \quad . \quad (27)$$

The effectiveness of these three solutions is best studied by means of an example. Suppose the losses are required for a stack of plates 8in by 4in, having a circular hole in the centre, the radius of the hole being $\frac{1}{2}$in, $\frac{3}{4}$in or 1in. Since the quantity P' is a common factor, it is only necessary to determine the value of Δ' and add it to L/G to show the relative losses for the various conditions. The following table is the result :

Radius of hole	½in	¾in	1in
R/G	0·25	0·375	0·5
The ratio L/G	2	2	2
Δ' (equivalent square)	0·11	0·31	0·51
Δ' (Schwarz and Christoffel)	0·15	0·28	0·53
Δ' (Hague)	0·17	0·41	0·83

The losses are, of course, $P'(2+\Delta')$.

The results for the equivalent square and for the Schwarz and Christoffel solution agree remarkably well and so does Hague's solution for the ½in radius hole. It would appear that Hague's solution gives higher values when the ratio R/G is large. The accuracy of these three solutions ought to be ascertained by experiment, but it has not yet

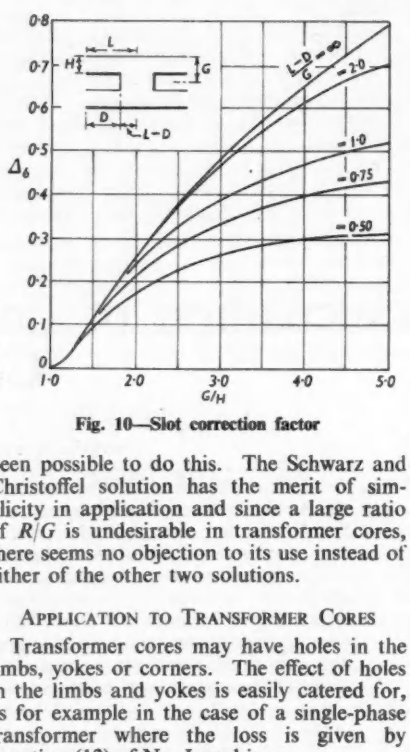


Fig. 10—Slot correction factor

been possible to do this. The Schwarz and Christoffel solution has the merit of simplicity in application and since a large ratio of R/G is undesirable in transformer cores, there seems no objection to its use instead of either of the other two solutions.

Application to Transformer Cores

Transformer cores may have holes in the limbs, yokes or corners. The effect of holes in the limbs and yokes is easily catered for, as for example in the case of a single-phase transformer where the loss is given by equation (12) of No. I, and is :

$$W=4P[(s/g)+(d/h)+\Delta_2)].$$

For holes in the limbs the s/g term requires replacing by an equivalent value which includes the correction factor Δ'. In a similar way holes in the yokes above or below the window space can be allowed for by an equivalent value of d/h. The case of holes in the corner is more difficult, since this requires a modification of Δ_2. A solution to this field problem has not yet been found so it is desirable to find an approximate solution. One way is to assume that the hole splits the limb flux into two parts. Then the core losses can be found by treating the core as two concentric structures, ignoring any flux constriction caused by the hole.

If the single-phase core given as the example in No. I has a bolt hole in each corner on the centre line of the limbs and yokes, then the value of g is 5in instead of 10in, with d_1=5in, and for the 10in yoke d_2=10in, s_1=20in and s_2=25in. The sum of the geometrical reluctances of the two structures divided by four may be verified to be as follows :

Yoke height	10in	15in
Geometrical reluctance	3·3	3·15

These values of the geometrical reluctance should be compared with the results obtained in No. I of this article.

Cruciform Cores

Here the core loss can be taken as the sum of the losses of a series of individual rect-

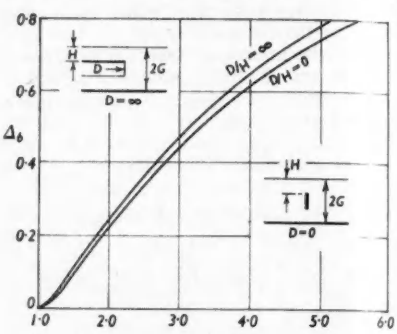


Fig. 11—Slot correction factor for variation of D/H

angular cores corresponding to each step. This assumes that there is no interchange of flux between each individual core. An interchange of flux, however, occurs if the yokes are not stepped in the same manner as the limbs, and if bolt holes cause excessive flux density in the vicinity of the holes. When flux interchange occurs, the actual losses are greater than calculated.

Flux constriction can be serious with cruciform cores, especially in the smaller steps. For if a core has a normal flux density of 13,500 gauss, then a 1in diameter hole in a 4in wide plate means a flux density of 18,000 gauss at the narrowest part of the plate. Such a flux density is about as much as can be supported by ordinary silicon iron.

Conclusions

While an assumption that the flux is uniformly distributed is satisfactory for determining the losses in toroidal cores, it is not so with the more usual rectangular single-phase and three-phase cores owing to the influence of the corners. With a more accurate analysis, an increase in the ratio yoke-height/limb width does not yield such a reduction in losses as determined from calculations based on a uniform distribution of

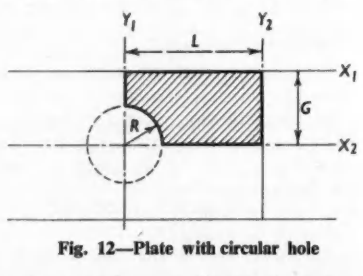


Fig. 12—Plate with circular hole

flux. There thus seems little to be gained by making the yoke height greater than the limb width.

Bolt holes are a serious disadvantage in transformer cores, not only because of causing higher losses, but also on account of constriction of the flux. Even holes in the corners are undesirable. Conditions are more serious with cruciform cores, for not only is the effective circle area reduced[11] by the bolt heads, but the smallest step width must be made wide enough to carry the flux in the reduced iron section around the holes. Bolt holes require careful consideration

when cores are constructed from grained oriented silicon iron if advantage is to be taken of a higher working flux density. The saturation of this iron is little greater than ordinary silicon iron, being around 20,000 gauss. Thus a working density of 17,000 gauss leaves far less margin for flux constriction than a flux density of 13,500 gauss, which is usual for ordinary silicon iron.

It is clear that bolt holes should be avoided altogether, so it is interesting to read of a proposed core for a 2,000,000kVA trans-

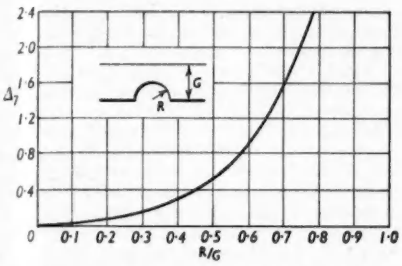


Fig. 13—Correction factor for circular hole

former in the U.S.A. without bolt holes.[12] If bolt holes are unnecessary in such a large core their avoidance in more conventional sizes should be perfectly feasible.

Appendices

(6) *The Dimensions (L−D) and D Infinite.* —The field solution for this case has been given by Carter.[9] It may be verified that :

$$\Delta_6=\frac{1}{\pi}\left[2\log\frac{1}{4}\left\{\frac{G}{H}-\frac{H}{G}\right\}+\left\{\frac{G}{H}+\frac{H}{G}\right\}\log\frac{G+H}{G-H}\right].$$

(7) *The Dimension D Infinite, but L−D Finite.*—The transformation from the t plane to the Z plane has again been given by Carter.[9]

$$\frac{dz}{dt}=\left[\frac{1-k^2t^2}{1-t^2}\right]^{\frac{1}{2}}\cdot\frac{Aksn^2\alpha}{1-k^2sn^2\alpha t^2}$$

giving upon integration and with appropriate constants

$$Z=\frac{2H}{\pi}\left[\frac{sn\alpha dn\alpha}{cn\alpha}u-\left\{uZ(\alpha)+\frac{1}{2}\log\frac{\theta(u-\alpha)}{\theta(u+\alpha)}\right\}\right]$$

where $t=snu$.

The field function is

$$\phi+j\psi=\frac{1}{\pi}\log\frac{\frac{1}{ksn\alpha}-t}{\frac{1}{ksn\alpha}+t}.$$

The mathematical operations to find the dimensional ratios and the value of $\phi_1-\phi_2$ follows somewhat on the lines shown by Cockcroft.[6] When the elliptic functions have been transformed for computation by means of the tables published by the Smithsonian Institute, it will be found that:

$$\frac{L-D}{H}=\frac{2K}{\pi}\left\{\frac{A(r)C(r)}{D(r)B(r)}-E(r)\right\}$$

$$\frac{G}{H}=\frac{L-D}{H}\cdot\frac{K'}{K}+\left(1-\frac{r}{90}\right)$$

and

$$\Delta_6=\frac{L-D}{H}\left(1-\frac{r}{90}\right)-\frac{L-D}{G}+\frac{2}{\pi}\log\frac{1}{B(r)C(r)\sqrt{k'}}.$$

The curves in Fig. 10 for the finite values of $(L-D)/G$ were computed by assuming values for both k and r.

(8) $D/G\rightarrow Zero$, $\frac{L}{G}$ *Infinite.*—This is the case for an infinitely narrow slot and the Schwarz and Christoffel transformation is

$$\frac{dz}{dt}=\frac{At}{(t^2-1/k^2)(t^2-1)^{\frac{1}{2}}}$$

giving

$$Z=\frac{2G}{\pi}\log\frac{k'+jk(1-t^2)^{\frac{1}{2}}}{(1-k^2t^2)^{\frac{1}{2}}}$$

Where

$$k'=(1-k^2)^{\frac{1}{2}}=\cos\frac{\pi}{2}\cdot\frac{G-H}{G}$$

The field function is

$$\phi+j\psi=\frac{1}{\pi}\log\frac{1-kt}{1+kt}.$$

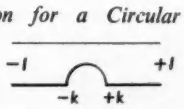
It can therefore be verified that

$$\phi_1-\phi_2=\frac{L}{G}+\frac{2}{\pi}\log\frac{1}{k'},$$

or

$$\Delta_6=\frac{2}{\pi}\log\sec\frac{\pi}{2}\cdot\frac{G-H}{G}.$$

(9) *The Field Solution for a Circular Hole.* — The function $Z=t+(t^2-k^2)^{\frac{1}{2}}$ transforms a straight line into a circle in the region $t=\pm k$. Thus the transformation for the figure is



$$\frac{dz}{dt}=\frac{A}{t^2-1}\left\{1+\frac{\lambda t}{(t^2-k^2)^{\frac{1}{2}}}\right\}.$$

λ has to be determined so that when $t=0$, y=radius of circle and when $t=\pm k$, x=radius of circle.

The integration of the expression may be found to be

$$Z=A\left[\frac{1}{2}\log\frac{t-1}{t+1}+\frac{\lambda}{2k'}\log\frac{\{t-k^2-k'(t^2-k^2)^{\frac{1}{2}}\}\{t+k^2+k'(t^2-k^2)^{\frac{1}{2}}\}}{k^2(t^2-1)}\right]$$

where

$$A=\frac{2}{\pi}\cdot\frac{Gk'}{k'+\lambda}\text{ and }k'=(1-k^2)^{\frac{1}{2}}$$

When $t=k$, $x=R$, so that

$$\frac{R}{G}=\frac{k'}{\pi(k'+\lambda)}\log\frac{1+k}{1-k'}$$

and when $t=0$, $y=R$, and then

$$\frac{R}{G}=\frac{2\lambda\sin^{-1}k}{\pi(k'+\lambda)},$$

λ can be found by equating these two equations, with the result that

$$\lambda=\frac{k'}{2\sin^{-1}k}\log\frac{1+k}{1-k}$$

the field function is

$$\phi+j\psi=\frac{1}{\pi}\log\frac{t-1}{t+1},$$

so that ϕ can be found in terms of Z by putting $t=1$ and performing the usual algebraic operations. Thus it might be verified that

$$\phi=\frac{L}{G}+\frac{2\lambda\log 1/k'}{\pi(k'+\lambda)}=\frac{L}{G}+\Delta_7.$$

The curve in Fig. 12 was found by writing $k=\sin\theta$ and assuming various values for θ. In the range from 60 deg. to 89 deg. λ was found to vary from 0·628 to 0·055 and R/G varied from 0·37 to 0·75.

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Air-Cooled Transformer Set for Arc Welding

An air-cooled transformer-operated arc welding set, with an output ranging from 20A to 190A and an open-circuit voltage of 60V, has been developed by The Quasi-Arc Company Ltd., Bilston, Staffs. It is designed and manufactured to comply with B.S. 638 : 1954, Group X.

The new equipment is known as the "ACP. 190" welding transformer set and its general appearance is shown in the accompanying illustration. It will be seen that the set is fitted with a towing handle at one end and a pair of solid wheels at the other. The set is 26¾in long by 14½in wide by 23⅝in high. It weighs 250 lb without the capacitor (30 lb) and undergear (8 lb), and it can be carried by means of two lifting handles.

Insulation of the welding set is Class "B" throughout. The transformer may be connected to supply voltages ranging from 190V to

Arc welding transformer set for welding currents of 20A to 190A with thirty-five intermediate steps

240V and 380V to 480V. There are eight primary terminals, mounted on the switch panel and the correct tapping for any applied voltage is obtained by means of a copper link which bridges any two terminals. A table giving the correct linkage for a specific voltage is mounted on the underside of the top cover of the welding set.

Using the two control handles on the top cover plate the operator can quickly select any of thirty-five current settings to suit a wide variety of work. At the lower end of the scale, from 36A down to 20A the current can be varied in steps of 1A or 2A. The maximum continuous hand welding current is 128·6A, the continuous rating (B.S. 171) being 5·4kVA. To remove the top cover giving access to the primary cable connections, it is necessary to remove both current selector switch handles, which is done by slackening the two Allen screws in each handle and then lifting off, and two screws in the side of the top cover at each end.

The welding set can be supplied with an inbuilt 2·2kVAr capacitor for power factor correction, and without undergear for static use

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Slip Gauge Maintenance Service. — Particulars have been received of a slip gauge maintenance service which has now been introduced by the Coventry Gauge and Tool Company, Ltd., of Coventry. One part of this service is for slip gauges used for general workshop purposes and it consists of deburring each slip, measuring for mean size and issuing a chart which classifies the result of the measurement under one of six columns. The first two columns represent the limits as shown in British Standards Specification No. 888/1950. The third and fourth columns represent grades of wear which, depending upon the use to which slip gauges are put, determines the future grading of the set. The fifth column indicates slips which may also be rejected, but which may still be acceptable for other classes of work. The sixth and final column indicates those slip gauges which are worn below 40 millionths under nominal size. A service for slip gauges for general inspection purposes which require more exact examination consists of a preliminary check to discover if they are worth subjecting to a full examination in accordance with the B.S.S. No. 888/1950. Under it a full report of the errors of each slip after testing for flatness and parallelism is made out and submitted to the user.

Electron Velocity Analyser to Stabilise a 50 kV D.C. Voltage Source to a Few Parts in a Million*

By M. E. HAINE, M.Sc., F.Inst.P., A.M.I.E.E., and M. W. JERVIS, M.Sc.Tech., A.M.I.E.E.†

For an experimental attempt to achieve a resolving power of atomic dimensions with the electron microscope,[2] a 50kV d.c. power supply, stable to a few parts in 10^6 over time intervals up to at least ten minutes was required. Considerations leading to the selection of a promising method of satisfying this requirement, and the development and operation of the apparatus,‡ are described. The method uses an electron velocity analyser to measure changes in voltage. The degenerative feedback circuit includes parallel d.c. and a.c. amplifiers. In operation, a stability of two to three parts in 10^6 is obtained on a 50kV supply.

Choice of Stabilising System

The degenerative feedback method, commonly used to stabilise a high direct voltage, is shown diagrammatically in Fig. 1.

A generator for the high voltage, e.g. a transformer-rectifier arrangement, feeds the load. A measure of the high voltage is obtained from a tap on a resistance potential divider. The voltage from the tap to earth is fed to the input of the d.c. amplifier via a reference battery which backs off the tap voltage to a suitable level for the amplifier input. The output of the amplifier modulates the high voltage in the sense necessary to correct any residual fluctuations present.

Stabilisers of this type have been described by previous authors[3,4,5] and, in general, stabilities to about 1 part in 10^4 are obtained.

Consider an arrangement of this type designed to stabilise a 50kV power unit in the presence

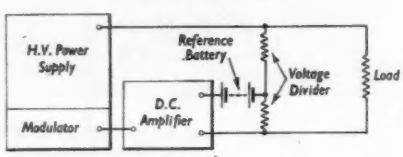


Fig. 1—Block diagram of conventional voltage-stabilising circuit

of initial fluctuations of 0·5 per cent such as may occur from the mains supply after passage through a constant-voltage transformer. A reasonable potential divider ratio would be 200 : 1, i.e. a reference voltage of 250V. For a stability within 2 parts in 10^6, the following conditions would have to be met :—

Amplifier gain × modulator gain × potential divider ratio = 2500.

Amplifier gain × modulator gain × 500,000.

Potential divider ratio and reference voltage stability = 2 parts in 10^6.

Amplifier input stability = 0·25mV.

The last two requirements present very great practical difficulties. Battery stabilities within a few parts in 10^6 are possible.[6,7] Amplifier input stabilities within 0·25mV are difficult to obtain over long periods, particularly with high input impedances which preclude the use of contact-modulator type amplifiers.[8] The conditions could be somewhat improved by using a lower potential-divider ratio and a reference battery of high voltage, but a really useful saving cannot be made, except by using a battery voltage so high that it becomes impracticable. In any case, the requirements for a potential divider ratio constant to 2 parts in 10^6 are likely to be extremely difficult to meet. Whilst this is not considered impossible, it is doubtful whether such a figure could be economically obtained.

For these reasons, other possible devices to replace the potential divider were considered. Finally, an electron-optical method was chosen, and it is the realisation of this method which is discussed in the paper. The method is shown to have the advantage over a resistance potential divider of increasing the signal level at the feedback-amplifier input from a fraction of a millivolt to a fraction of a volt at least.

The Electron Velocity Analysing Method

The principle of the stabilising method used is to accelerate a beam of electrons through the voltage to be stabilised, to measure the velocity by deflection in a fixed magnetic field, and so to obtain a signal to the feedback amplifier. Similar methods have been described before,[9,10] but only for stabilities within a few parts in 10,000.

There are many possible methods of analysing or measuring the velocity or velocity distribution

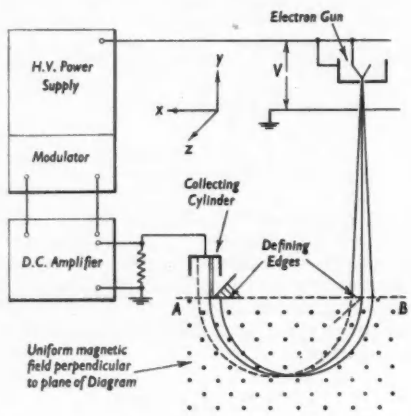


Fig. 2—Block diagram of velocity-analyser voltage-stabilising circuit

of a stream of charged particles. The one chosen, the 180 deg. magnetic velocity analyser, is not the best, since it suffers from electron optical aberrations which are avoided in others, but it was considered the most convenient for the present work, and other systems are not discussed in the paper.

The electron beam is directed into a uniform magnetic field (Fig. 2), in a direction perpendicular to the field. It is well known that the beam is then deflected in the field in the arc of a circle. If the magnetic field is limited at a boundary *AB* perpendicular to the direction of the incoming beam, the beam emerges from the field in a direction opposite to that of incidence.

It will be seen later that, in order to detect a fractional change in voltage of 1/500,000, changes in the position of the beam at the output must be detected of the order of 1/1,000,000 of the radius of the electron path. In a conventional type of velocity analyser such measurements are made by defining the width of the beam at the analyser input with a slit system. This is necessary in a true spectrometer, which serves the purpose of measuring a distribution of energies or masses analysed by the action of the deflection field. In the present instance, only one mass and one energy are present at a given instant. However, a slit system could still be used and has been considered, but the rather simpler arrangement illustrated in Fig. 2 is preferred. The beam from the electron gun, after deflection in the analyser field, falls on an earthed defining edge which cuts off most of the beam and allows only a small fraction to pass into a collector cylinder. The current from this cylinder is passed through the grid resistor in the input stage of the feedback amplifier. It will be seen that an increase in voltage on the electron gun increases the beam orbit diameter, and hence the collected current, thus producing a negative signal to the amplifier.

[The authors then discussed various design considerations, including the effect of variations in the electron gun current, analyser aberrations, beam intensity and sensitivity, and electrical effects.]

Mechanical Vibration.—Spurious changes will result if the two knife edges move relatively. For the conditions of the above example, the knife-edge separation must be stable within $x_D \times 10^{-6}$, or 0·15 micron for $x_D = 15$cm.§ This presents some difficulty, but seems by no means impossible, particularly since the knife edges can be supported at either end of a rigid bar.

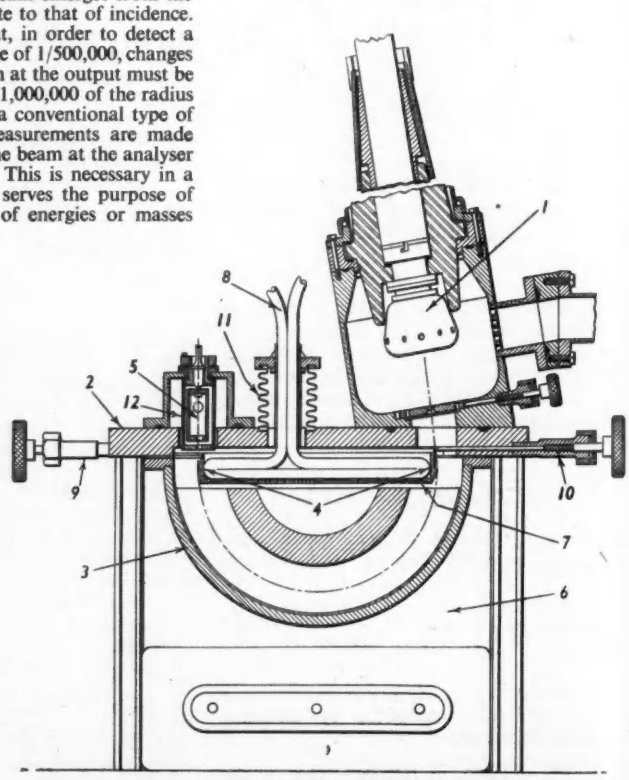
Thermal Expansion.—Thermal expansion will cause variations in the magnet field, and in the distance between the defining edges. A typical temperature coefficient of 20 parts in 10^6 per degree Centigrade leads to a temperature stability requirement of $^1/_{20}$ deg. Cent. for a voltage stability of 2 parts in 10^6. This could be reduced by using materials of low coefficient of expansion or by compensation. As will be seen, an even smaller temperature tolerance is set by the temperature coefficient of the permanent magnet used to produce the deflecting field.

Magnetic Field Variation.—Since the diameter of the electron orbit in the analyser is inversely proportional to the magnetic field, it is clear that the high voltage cannot be more stable than the magnetic field strength. Three possible methods of exciting the magnet gap have been considered : a permanent magnet, an electromagnet supplied from a stabilised current source, and an electromagnet connected in series with the electron microscope objective lens. This last method has a further advantage which is discussed below.

Permanent magnet excitation is attractive in that it eliminates the necessity for any associated circuits. Modern permanent magnet alloys have temperature coefficients of about 1 part in 4000 per degree Centigrade,[12] so that the temperature must be kept constant to 0·01 deg. Cent. to maintain the field constant to 1 part in 500,000. To minimise drift in the strength of the magnet, it should be over-excited and then stabilised by the application of an a.c. field.

The possibility of compensating the magnet against variation due to temperature changes, by using shunts of magnetic material whose per-

§ Where x_D = diameter of electron orbit, cm.



Distance between vertical support rods = 25cm.

Fig. 3—Cross section of 180 deg. magnetic velocity analyser

* Abstract. Measurements Section paper, Institution of Electrical Engineers, London, December 14th.

† Research laboratory of Associated Electrical Industries, Ltd.

‡ A brief description of the principles of the stabiliser was given at the International Conference on Electron Microscopy held in Paris, September, 1950.[1]

meability is temperature sensitive,[15] has been considered, but has not so far been applied.

An electromagnet requires a current supply stable to 1 part in 500,000, although it is possible to operate it in series with the electron microscope objective lens, in which case the change in focal length due to a current change in the lens would be compensated by the high-voltage change resulting from the same change in current occurring in the analyser magnet. This compensation would be exact only where ion saturations, if present, were identical in both magnet and lens. It is difficult to achieve these conditions in practice.

A further possible cause of variation in the deflector field lies in the varying stray fields arising from, e.g. nearby transformers. The maximum permissible stray field for a total deflector field of 100 oersteds is 0·2mG. This is roughly equal to the stray field measured in the laboratory, where precautions had already been taken to minimise stray fields because of interference with the electron microscope itself. An advantage of the electromagnet is that it provides a large degree of shielding against stray magnetic fields. The permanent magnet arrangement is poor in this respect because of the low permeability of the permanent magnet material under operating conditions.

The Practical Realisation of the Velocity Analyser

Velocity Analyser.—The analyser system finally used is shown in Fig. 3. It consists of an electron gun 1 similar to that developed for an electron microscope,[14] using a 0·005in tungsten wire

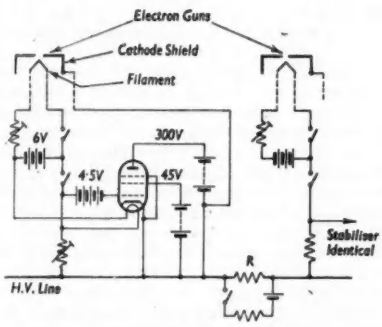


Fig. 4—Circuit diagram of h.v. electron-gun current stabiliser

hairpin as cathode, a biased cathode shield, and earthed anode plate. The anode plate can be adjusted laterally to centre the electron beam as described,[11] which deals comprehensively with the performance and characteristics of this type of electron gun.

The electron gun is mounted directly on to the 180 deg. analyser top plate 2, its axis making an angle of 6 deg. to the top edge of the magnet. The tilt of the gun is desirable because the electron beam is deflected by the fringe field of the magnet before passing into the region between the magnet pole pieces. For the spectrometer aberrations to have a minimum effect, the electron beam axis should be perpendicular to the line joining the input and output defining edges of the spectrometer. The angle of 6 deg. was computed from the magnetic field distribution measured on a resistance network analogue.[15]

The analyser itself consists of the semi-circular brass vacuum vessel 3 with rectangular top flange, the defining edges 4, the collector cylinder 5, and the magnet 6. The vacuum vessel has a copper liner which can be removed for cleaning. It is important, as in most electron optical systems, to avoid contamination by insulating layers which may become charged by stray electrons to a potential sufficient to deflect the main electron beam.

The defining edges are machined in a single brass bar 7 with copper inserts soldered in at the ends. The actual edges are lapped straight to microscopic tolerance and tapered on the back to allow the electron beam to spread without interception. It is important that the edges should be accurately parallel, as has already been mentioned. The copper blocks are fitted with an oil cooling pipe 8 soldered into a hollow which is milled lengthwise. Adjusting screws 9, 10, enable the first edge to be centred in the incoming electron beam by traversal in the *X* direction. The oil connections are taken out through a flexible metal bellows 11.

The collector is a shielded and insulated cylinder, with an entry aperture arranged to collect the beam which spills over the second defining edge and to trap as many back-scattered electrons as possible. It must be borne in mind that, at voltages of 50kV to 100kV as much as 60 to 70 per cent of the beam falling on a metal surface can be lost by back scattering. A coating of graphite is applied to minimise this loss.

A separately insulated second apertured box 12 is fitted round the collector, and serves to indicate (by absence of any current reaching the electrode) correct alignment and adjustment of the beam.

The permanent magnet consists of two rectangular slabs of ½in thick mild steel measuring 9in×7in, spaced 0·75in apart. Excitation is produced by a solid cylinder of Alcomax II permanent magnet material fitting between the pole piece slabs. This arrangement represents a very efficient use of the permanent magnet material since the drop in magnetomotive force along it is uniform and none of the material is wasted. It also results in a simple design for the permanent magnet, since no allowance for demagnetisation by unknown leakage flux of the magnet itself need be made. The deflecting field for 100kV electrons (the maximum voltage allowed for in the design) is 150 oersteds. This can be obtained with a 2cm length of Alcomax II operating at a flux density of about 10kG. The magnet area required is therefore about 9 square centimetres.

The alternative electromagnet comprises two Mumetal poles of the same size as those in the permanent magnet system, and a Mumetal core of cross section large enough to keep the flux density of the core below 5000G. The core is excited by a winding capable of giving a flux density up to 150G in the gap. This magnet gives a current/flux density relation which is linear to within 0·1 per cent and a flux density differing by less than 0·1 per cent from that in another similar magnet, excited in series with it. This is of importance in one of the tests applied to the system.

Temperature Stabilisation.—The magnet assembly is immersed in an oil-filled tank kept at a constant temperature of 28 deg. Cent. by a mercury-toluene regulator with thyratron relay controlling the heater. The heater is a 60W electric light bulb, which provides heating with a small 50 c/s magnetic field. The oil is stirred by small d.c. motors fitted 3ft from the magnets. The temperature of the bath is stable within about ±0·01 deg. Cent. A small gear pump attached to one of the stirrers pumps oil through the defining edge cooling pipe.

Electrical Circuits

Electron Gun Supplies.—Normally, the electron gun of the electron microscope operates with a bias obtained from the voltage drop in a resistance in series with the main high voltage (self-bias). In the stabilising arrangement at present employed, it is desirable to connect the microscope and analyser cathodes directly together electrically, as the stabiliser effectively stabilises the potential at its cathode, and any intervening circuit would be likely to introduce a varying potential on the microscope cathode relative to the analyser. On the other hand, it has been seen [Section 3.1 of the paper, not reproduced here] that the analyser beam current should be stable to better than 1 per cent. It is difficult to achieve this stability without self-bias unless some form of current stabiliser is used. Fortunately, it was possible to devise a very simple circuit giving a current stability of about 1 part in 1000.

Circuits for cathode heating, biasing and current stabilising are mounted on a platform insulated for 100kV from earth. The circuit arrangement is shown schematically in Fig. 4. Two identical circuits are included to feed two electron guns, although only one stabiliser circuit is shown in the figure. Filament heating is obtained from 6V car type accumulators. An on-off switch and a rheostat control are operated by means of long insulating rods. The current stabiliser comprises a single degenerative amplifier stage using a type "6F13" pentode valve. A small reference resistance, in series with the high-voltage supply, produces the control signal, which is fed to the grid of the valve through a 4·5V battery. The output of the amplifier provides the bias to the electron gun.

Provision is made for injecting a fixed voltage across the resistor *R* (Fig. 4) connected in the high-voltage line between the two electron guns. This voltage is used to calibrate monitoring equipment and to introduce accurately known fractional changes in the focus of the microscope.

High-Voltage Supply.—The high-voltage power unit consists of a voltage-doubling Greinacher circuit with a resonant air-cored transformer energised by a 25 kc/s oscillator. The arrangement is very similar to that used in the electron microscope described by Haine, Page and Garfitt.[14]

Feedback D.C. Amplifier.—To maintain a stability of 2 parts in 10^6 in the presence of variations of input and load of 1 per cent, an overall feedback gain of 5000 is required. If the zero frequency gain of the modulator is 250, and that of the analyser about unity with a 5 megohm load, an amplifier gain of at least 20 is desirable. The input to the amplifier must be stable to within 0·1V.

The amplifier is conventional in design except that care had to be taken to make the gain independent of frequency over the range 0 kc/s to 50 kc/s and that low-grid-current valves are used in the input stage. The output valve feeding the screen grid of the oscillator stage is a cathode follower. A micro-ammeter in series with the input resistor indicates the overlap current collected in the collecting cylinder ; this current is adjusted by means of a variable direct voltage

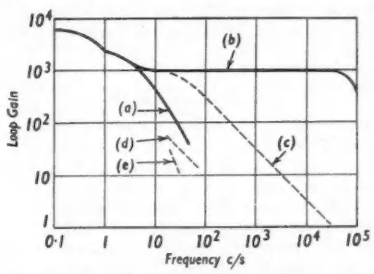


Fig. 5—Loop-gain/frequency characteristics of feedback loop with and without the modification produced by a.c. feedback amplifier and stabilising time-constant

in series with the micro-ammeter. When correctly adjusted, the high voltage recovers automatically after a large disturbance such as a flashover of the microscope gun. A reduction in high voltage causes the overlap current to fall to zero, so applying maximum screen voltage to the oscillator valves and re-establishing the stabilised voltage.

Self-Oscillation and Frequency Response.—Bode[16,17] has shown that, with certain reservations, the oscillation stability of a feedback amplifier can be judged from the log-gain/log-frequency characteristic. Instability results if the gain is greater than unity at the point where the negative slope of the characteristic exceeds 2 ; at this point the phase shift is 180 deg. The frequency response of the h.v. power supply was measured, and is shown in curve *a* of Fig. 5. A maximum stable gain of only 100 would be expected from the Bode criterion ; this was approximately confirmed by experiment. Not only is the circuit unstable, but the gain at 50 c/s and harmonics of 50 c/s is too low to allow mains frequency and harmonics to be reduced appreciably by the stabilisation. For larger gains to be applied, it is clear that the frequency response of the feedback loop had to be modified so as to make the gain fall off more slowly with increasing frequency. The parts of the circuit causing the rapid fall-off were the oscillator and smoothing circuit. Improvement was achieved by the use of an auxiliary a.c. feedback loop, by-passing the h.v. power unit from oscillator screen grid to the h.v. line. This amplifier consists of one pentode stage and a cathode follower connected from the output of the d.c. amplifier to the earth side of the final smoothing capacitor. A spark gap and non-linear resistor are connected across the load resistor for protection against h.v. surges.

The improvement resulting from the insertion

of this amplifier is shown in curve *b* of Fig. 5. The gain is now constant up to 50 kc/s, but oscillations would still occur at about 200 kc/s, where the slope of the characteristic reaches −2. This instability can be prevented by lengthening one of the time constants to give the dotted curve *c* in Fig. 5, so reducing the gain to unity before the slope reaches −2. For comparison, slopes of −1 and −2 are shown by the short dotted curves *d* and *e*. In practice, the large time constant was applied in the form of a capacitor across the input of the d.c. amplifier input resistor. By adjustment of this capacitor and the a.c. amplifier gain control, a total stable loop gain of up to 5000 was obtained. The insertion of the loading capacitor in this position has the incidental advantage of reducing the input impedance of the amplifier, and hence the possibility of pick-up of stray transient voltages.

Auxiliary Analyser.—In addition to the main stabilising analyser, a second identical analyser is available. The second analyser can be switched in place of the first as a standby in case of filament or other failure, or it can be used as a test monitor to check the h.v. stability. The output of the second analyser is recorded on a 4in chart recorder via a d.c. amplifier. This arrangement has a sensitivity capable of showing a change in high voltage of 1 part in 10^6 per millimetre division of the chart. The stability of the amplifier corresponds to changes of less than 1 part in 10^6 in the high voltage.

[The authors then described the test procedure they adopted for measuring the performance of the stabiliser system.]

Results

Typical test results for the apparatus as described when first operated are enumerated below :

Beam current stability	1 in 10^6 (for 1 h)
Equivalent stability at stabilising analyser output	1 in 10^7 (for 1 h)
Ripple voltage	2 in 10^6
Long-term drift	Up to 10V1min

The high equivalent stability at the analyser output indicates that adequate feedback gain is available, and that spurious fluctuations in the amplifier and modulator are negligible, so that any measured voltage fluctuations must result from instability in one or both of the analysers. The ripple voltage was excessive and was subsequently reduced by minor circuit changes to 4 parts in 10^6.

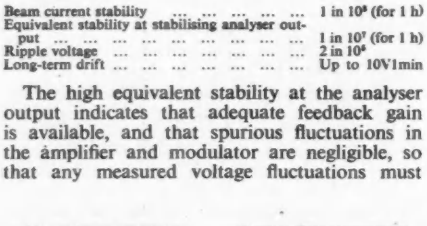


Chart scale in (*a*), (*b*) and (*c*)=6 parts in 10^6 per vertical division.
Chart scale in (*d*)=3 parts in 10^6 per vertical division.

Fig. 6—Typical test records from recorder with 1V calibration changes

It was not possible to ascertain whether observed variations result from the stabilising analyser or the measuring analyser, and it was therefore necessary to attempt to improve both. In the first attempt, the actual overall temperature coefficients of the analysers were measured by causing large changes in the temperature of one oil bath and measuring the indicated change in high voltage. In this way, for the permanent magnets, a temperature coefficient of 1 part in 4000 per degree Centigrade was measured, while for the electromagnets the measured value was 1 part in 20,000 per deg. Centigrade. Since the temperature was found by measurement to remain stable to 0·01 deg. Cent., voltage changes of not more than 1 part in 400,000 should result.

The main source of drift was found to be incorrect alignment of the analysers. In particular, it was found that over the first ten to fifteen minutes of operation the electron gun filaments tended to move, thus moving the electron spot at the analyser input. By delaying the final alignment until after such an initial period of operation, a considerable improvement was obtained. Finally, the drift was reduced to about 1 part in 10^6 per minute, with some day-to-day variation. The overall stability then obtained is shown in the records of typical runs in Fig. 6. The stability can usually be relied upon to 2 to 3 parts in 10^6 for minute intervals. The ripple is still 4 parts in 10^6, but it is known that this can be reduced, and steps in this direction are being taken in a new h.v. power unit.

The results given were obtained with the electromagnets which were excited in series, so that the variations in excitation current were automatically compensated as previously described. A current stabiliser, giving a stability of 3 to 4 parts in 10^6 has now been developed by Jervis,[18] and is in operation feeding the microscope objective lens and the stabilising analyser. Results with the permanent magnets have shown comparable results.

Conclusions

A voltage stabilising system has been constructed capable of stabilising a h.v. d.c. supply to a few parts in 10^6 over most ten-minute periods. It is felt that stability over longer time intervals could be achieved, but further experimental work is necessary to locate the causes of residual drift.

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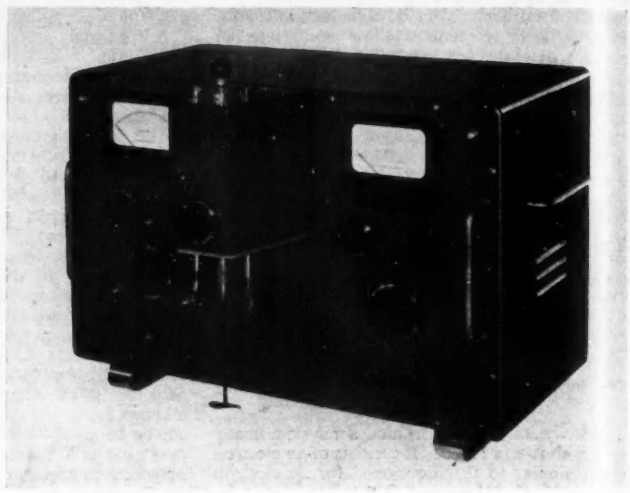
Electrolytic Polisher

An electrolytic polisher has been developed by Nash and Thompson, Ltd., Tolworth, Surrey, as a laboratory instrument for polishing metallurgical specimens. It is based on a method which was devised by P. Jacquet* and his associates in France.

Briefly the process consists of using the specimen that is to be polished as the anode in a solution which is specific for each metal. When current is passed through the solution the distorted surface layer of the specimen is removed by electrolysis and the surface is left with a high polish.

An advantage claimed for this process is that the true structure of the metal is revealed by the subsequent etching, whereas, in the usual methods of polishing, unless great care is taken in the final stages, the structure of the metal, as revealed by etching, may be disguised by distortion and spreading of the surface layers.



Electrolytic polisher for specimens up to 4 square centimetres. All the controls are on the front panel. The central projection houses the electrodes and stirrer

In general it has been found† that electrolytic polishing is satisfactory in the case of single phase alloys and multi-phase alloys where all the phases are solid solutions. It is not generally suitable for polishing metals or alloys containing intermetallic phases because these phases usually have electro-chemical properties very different from those of the matrix ; consequently there is bad relief between the matrix and the intermetallic compounds. But because of the difference in polishing in the various phases, electrolytic polishing gives an exaggerated representation of the amount of the second phase. This characteristic may be useful in instances where the second phase is present in only very small amounts (*loc. cit.*).

A general view of the Nash and Thompson electrolytic polishing equipment is reproduced here. The apparatus is housed in a rectangular sheet metal box, with the fittings and controls mounted on the front panel. At the middle of the panel and toward the top is the mounting for the electrodes and the stirrer. They are arranged so that they may be lifted and locked in the raised position to facilitate the removal of the beaker in which the specimen is polished.

The working range of the instrument is 0 to 70V, with a maximum current of 5A. The direct current is smoothed to about 1 per cent (a very slight " ripple " is believed to be advantageous for some polishing). Both current and voltage are indicated by flush-mounted meters and control is effected by a variable auto-transformer.

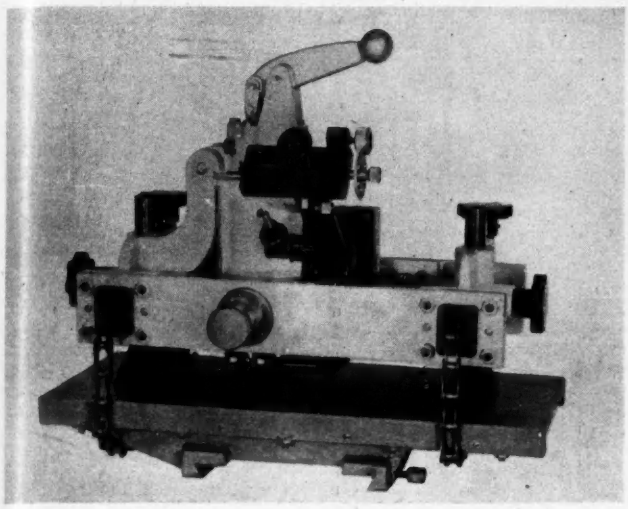
Fine control is provided for the low voltage ranges. A short-circuiting switch is provided for use in etching the specimen in the polishing solution, if required. The stirrer has variable speed control.

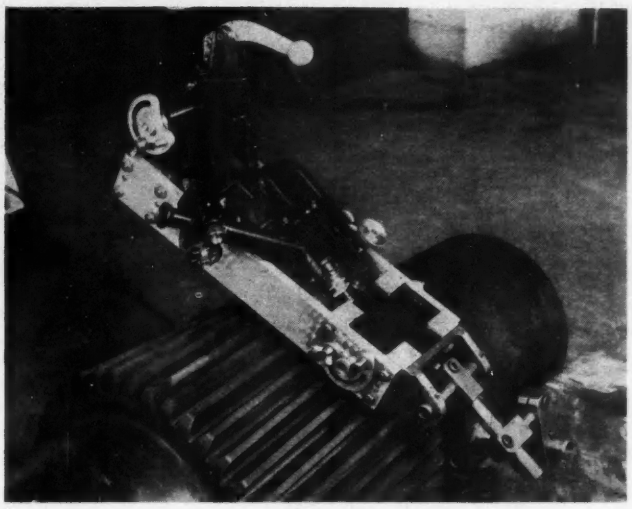
The electrode connections can be released very quickly so that the specimen can be rapidly removed for washing at the end of the polishing operation. Cathodes are made of different materials for the different solutions and a range of cathodes is available in copper, aluminium and stainless steel. A glass cooling coil can also be provided, as some solutions need a high current which generates considerable heat. Polishing solutions are not supplied. A small hot plate is available as an extra item.

We learn from the maker that this apparatus has been successfully used for the polishing of copper and copper-base alloys, aluminium and its alloys, low carbon steels, titanium and molybdenum.

* P. Jacquet, *Comptes Rendus*, 1935, 201, 1473.

† E. C. W. Perryman, *Metal Industry*, July 1951.





Portable diamond indenter hardness tester. On the left the tester is shown clamped to the workpiece. On the right it is shown in use for examining teeth in a marine gear

Portable Diamond Indenter Hardness Testers

PARTICULARS have been received from Vickers, Ltd., of two new forms of its diamond indenter hardness testers which have been developed for use in research and production work, where the workpiece to be tested is too large or heavy for the standard machine.

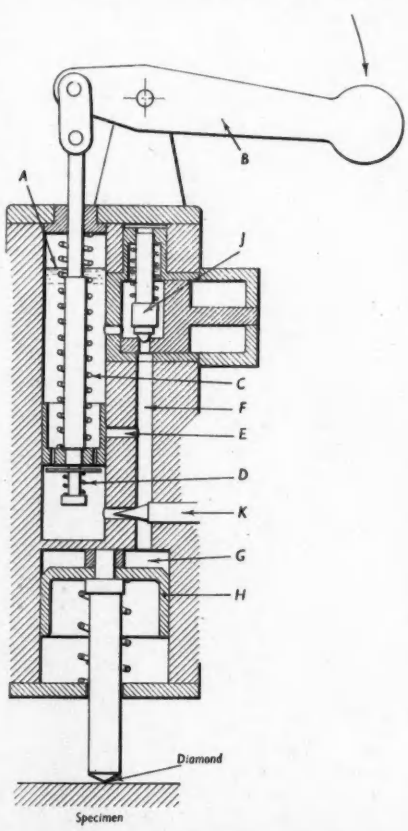
One of the instruments now introduced is the portable machine shown in the first illustration. This machine is attached to the work by means of 1in pitch roller chain clamps which are adjustable for length to suit the size of the piece to be tested. It consists essentially of an adaptor body carrying an indenting unit with a standard diamond indenter and a microscope for measuring the impression. Two alternative indenting loads of 10 kg and 30 kg are readily available by setting a knob on the machine.

As in the standard Vickers hardness testing machine the impression is made by a pyramid diamond but instead of being applied through a series of levers the load is imparted by a spring operating in conjunction with a hydraulic system. The operation of the indenting mechanism can be seen with reference to the accompanying drawing.

The operating handle is coupled directly to a spring-loaded compression piston which is, in turn, connected hydraulically with the indenting spindle carrying the diamond. The body is filled with oil to the level *A*. When the operating handle *B* is depressed it raises the piston and compresses the spring *C* which is capable of providing a load in excess of the rated load. The inequalities of pressure on each side of the piston cause the non-return valve *D* to open and permits oil to flow from the exhaust to the compression space below it. At the end of the manual stroke the pressures are equal, and the valve *D* closes under the influence of its spring. The by-pass *E* is closed by the piston throughout this stroke.

Upon release of the handle, the impression stroke commences. The piston is moved downwards by expansion of the spring and oil is forced into the load valve chamber *F*, and the indenter-operating cylinder *G*, causing the light spring behind the piston *H* to be compressed until the indenter comes into contact with the work. Immediately contact is made the pressure builds up in the system until the full indenting load is being applied to the diamond. When the full load is reached, the valve *J*, which can be adjusted for release pressure, prevents any further increase by opening slightly against its spring and allowing oil to flow to the exhaust space. At the end of its stroke the piston uncovers the port *E* and the pressure is released, oil being permitted to flow into the exhaust space when the light spring returns the indenter piston to its retracted position ready for the next operation. The load valve spring is pre-set to give the correct load and no further adjustment is necessary unless correction of the load is required. The impression period of approximately ten seconds is controlled by the adjustable throttle valve *K*, which is locked after setting to ensure constant conditions for each impression.

In order to obtain a compact assembly, with a minimum amount of adjustment between the indenter and the microscope objective, a horizontal objective extension is fitted to the microscope. By a system of reflectors, this extension, in effect, brings the objective to a distance of only 0·6in from the indenter. Thus it is necessary only to move the microscope a distance of 0·6in in order to measure the impression. Apart from this horizontal extension, the microscope is very similar to that used on the standard hardness testing machine. The microscope is rigidly attached to the indenting unit by a light alloy bracket, from which it is readily detachable.



Arrangement of spring-operated hydraulic loading system of indenter mechanism

The adaptor, or carriage of the instrument, is built up of a pair of duralumin side plates secured to and spaced apart by two light alloy brackets, each of which houses a vertical steel tube projecting below the adaptor. Each tube has a specially shaped steel foot attached, and these feet, which serve to support the tester on the specimen, are adjustable for height, in order to obtain the correct spacing between indenter and specimen. The indenting unit is mounted in the adaptor in a pair of steel bearings, one secured to each side plate. A short steel spindle projects from each side of the indenting unit and registers in one of the side plate bearings.

Through its bearing mounting the indenting unit can slide transversely between the side plates for a distance of 0·6in to bring the objective into position over the impression. Ball catches acting on grooves in the indenter mounting spindles retain it in either of its positions in the adaptor.

Another of the photographs we reproduce shows the second of the new testing machines being used in the examination of teeth on a large marine gear. This machine is generally of similar design to the one described above except that the indenter operating cylinder and the microscope are set at an angle to enable the impression to be made in an otherwise inaccessible surface, and the reading to be taken with ease. Its method of attachment and support are also adapted for the particular shape of the workpiece.

ASLIB AERONAUTICAL GROUP.—The fourth annual conference of the Aslib Aeronautical Group is to be held at Cranfield, Bedfordshire, from Friday to Sunday, April 1st to the 3rd, 1955. The main discussion at the conference will centre on "Classification," and the Classification Research Group will take part. Under the chairmanship of Mr. B. I. Palmer, education officer of the Library Association, this group has been meeting during the past three years to consider certain fundamental aspects of classification. During the same period the Aslib Aeronautical Group has been investigating non-conventional methods of retrieving information. The conference committee invites contributions from anyone interested in the work of the groups, and for this purpose papers have been written by Mr. B. C. Vickery and Mr. C. W. Cleverdon describing the work of their respective groups in this field. Copies of these two papers and further particulars concerning the conference can be obtained from Mr. C. W. Cleverdon, College of Aeronautics, Cranfield, near Bletchley.

Gear Roll Testing Machine

A NEW gear roll testing machine now being made by the David Brown Tool Company, Ltd., Huddersfield, is designed to provide a simple, rapid and positive means of checking concentricity, centre distance and varying tooth thickness of gears up to 24in diameter. The standard machine accommodates external or internal spur or helical gears, as shown in one of the illustrations on this page. By fitting separate heads on the adjustable carriage, one of which is shown in the second illustration, shaft gears, bevel gears and worm gears can be checked. On the machine a dial indicator registers the readings, whilst a vernier scale shows the centre distances.

The rigid bed of the machine has accurate slideways on which the adjustable and sensitive carriages are located. The adjustable carriage is moved along its two guide ways, one of vee section and one flat, by a handwheel which operates a pinion meshing with a rack, and it can be locked in any required position.

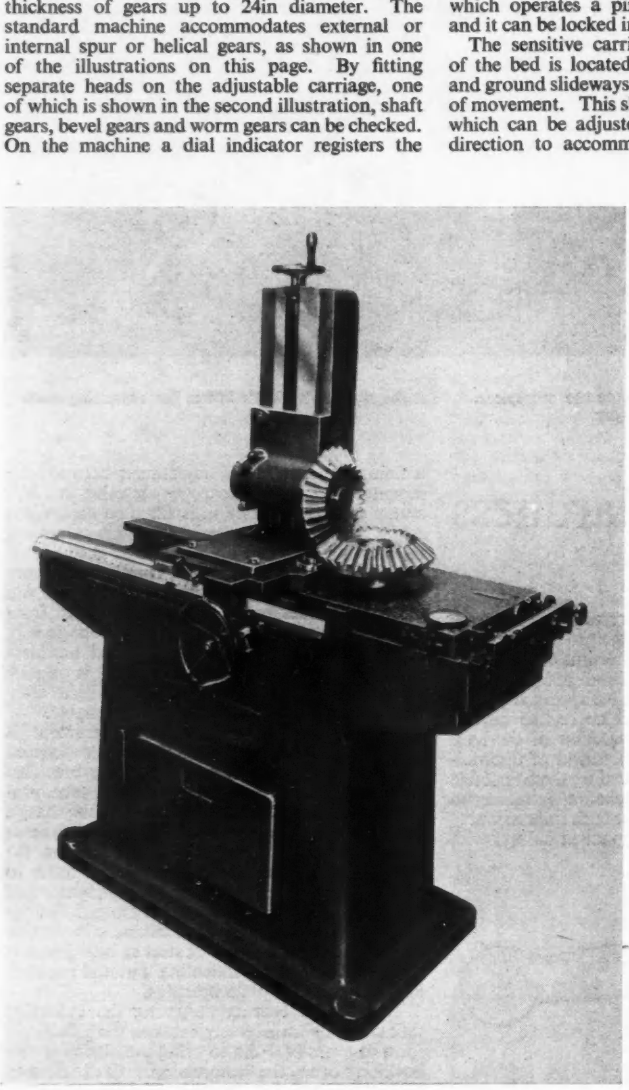
The sensitive carriage at the right-hand end of the bed is located on four balls in hardened and ground slideways to ensure complete freedom of movement. This slide operates spring pressure which can be adjusted and exerted from either direction to accommodate external or internal gears, an indicator pin being fitted to show in which direction the spring is acting. A screw can be used to adjust the dial indicator or it can be set at zero by rotating the dial. When it is required to check gears sufficiently large to cover the carriage the indicator dial can be set in an auxiliary bracket at the side of the carriage. A screw-adjusted stop is fitted to prevent the carriage overrunning and damaging the indicator. A scale attached to the sensitive carriage extends along the front of the bed, and through a vernier fitted to the adjustable carriage an accurate means of measurement is provided when checking gear centre distances.

On the machine gears are tested by rotating them together in pairs. When quantities of gears are to be tested it is recommended that one of the gears should be a master or one that is known to be correct. Using the respective arbors, the adjustable carriage is moved along the bed to bring the gears into mesh. The carriage is then clamped in a position where it will exert a slight spring pressure against the sensitive carriage. On rotation, any variation in concentricity or tooth thickness is immediately registered on the dial indicator and the centre distance at which the gears are meshing is read on the vernier scale.

For batch inspection, the adjustable carriage is returned to the same position after each gear is checked, by using the stop fitted to the bed. Backlash can be calculated by noting the difference between the working centre distance and the centre distance when the gears are in metal-to-metal contact.

A centre attachment which can be fitted to the adjustable carriage enables shaft gears up to 10in diameter and 20in overall length to be accommodated. The bevel attachment shown in position on the adjustable carriage in our second illustration can be used for straight or spiral bevel gears. With this attachment apex distances are read from a vertical vernier scale, which is set to zero from the face of the arbor locating bush on the sensitive carriage and from the vernier set on the bed. When several bevel gears are to be tested the adjustable stop on the bed is used.

A worm checking attachment for the adjustable carriage accommodates worms up to 10in diameter. The worm support brackets can be adjusted to locate shafts of different lengths which can be mounted on bushes or between centres. A horizontal slide which carries the brackets can be offset up to 5 deg. either side of the centre, measurements being read from a circular vernier scale. With this construction it is possible to ascertain the amount of correction or adjustment necessary for the worm wheel generating machine to obtain correct contact markings.

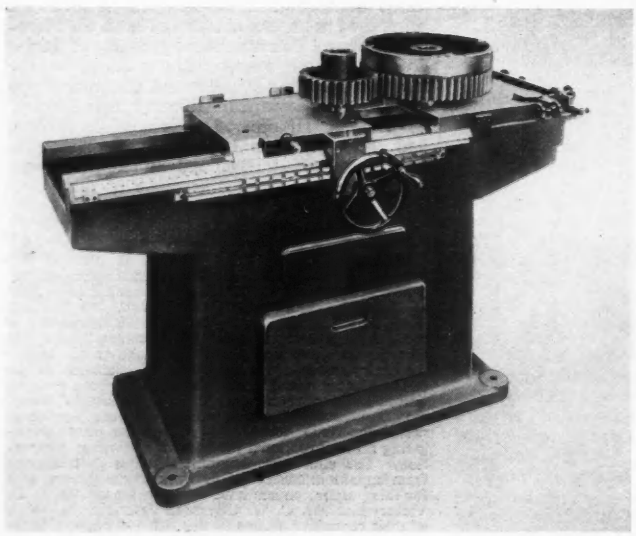


Gear roll tester fitted with head for testing bevel gears

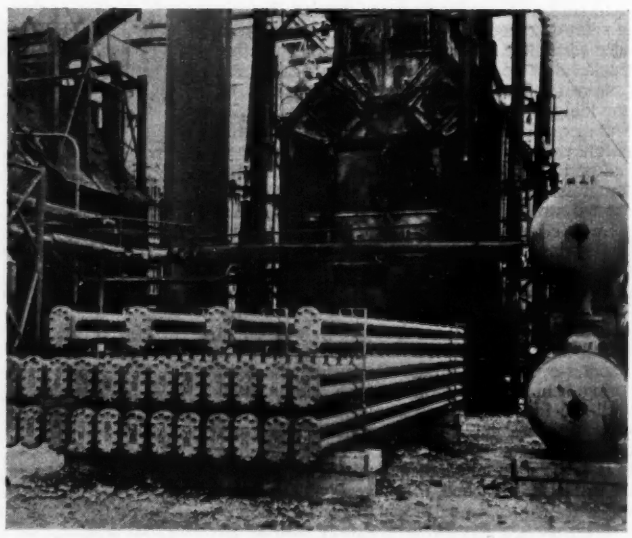
Finned Tube Heat Exchangers

HEAT exchangers fitted with finned tubes are now being made in this country under American patents by Birwelco, Ltd., Chester Street, Birmingham, and marketed by a subsidiary company, Brown Fintube (Great Britain), Ltd.

The finned tubes used as the inner elements for these exchangers consist essentially of a plain tube to which sheet metal fins are welded. The fins are formed in pairs by strip metal rolled into "V" or "U" shape and they are fixed to the outer surface of a plain tube by a continuous welding process. Finned tubes can be arranged in bundles in a heat exchanger shell, or they can be made up into "double pipe" or "hairpin" elements. In these elements the finned tube is inserted into a shell in the bore of which the fins register to act as spacers and centralise the inner tube. The outer tubes have connecting headers welded on to them and at one end the finned tubes are connected by a "U" shaped tube. This construction provides a passage between the inner and outer tubes through the fins for one liquid and through the centre of the



Standard gear roll tester, suitable for testing external or internal spur and helical gears up to 24in diameter



Heat exchanger battery of hairpin sectional elements at an oil refinery

inner tube for the second fluid. These hairpin elements are so designed that they can be used alone or a number can be connected in series to suit any required duty. A typical battery of coupled elements of this kind can be seen in the photograph we reproduce on this page.

A number of advantages are claimed for heat exchangers built with the finned tubes. The large surface presented by the fins on the inner element reduces the amount of tube required and thus the space needed to fit a heat exchanger. Certain fluids pick up heat less readily than others and the design makes it possible to arrange for one fluid to contact a bigger surface area than the other.

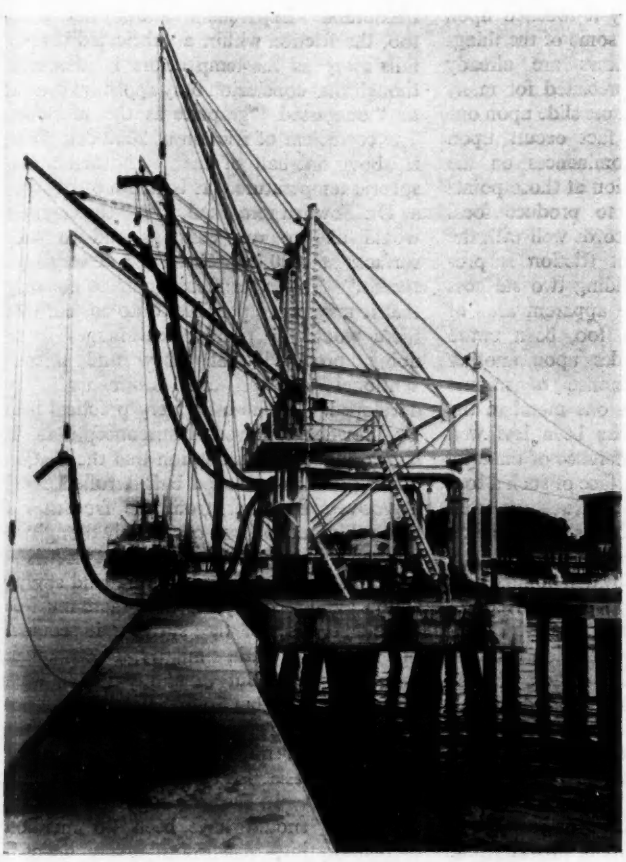
The finned tube "hairpin" heat exchanger elements are being made by the company with four standard shell diameters of 2⅜in, 3½in, 4in and 4½in and four standard finned tube sizes of 1in, 1·9in, 2⅜in and 2⅞in outside diameters. These standard tubes and shells can be combined to give ten different standard combinations with fin height to suit the differences in shell/tube diameter in each case. The elements are available in standard lengths with 5ft, 10ft, 15ft and 20ft nominal fin lengths, with a 4in length of pipe extending at each end beyond the fins.

Oil Berths at Singapore

AT Pulo Bukom, Singapore, four new oil tanker berths are under construction and when complete will be able to accommodate super tankers of up to 60,000 tons displacement. The new shore facilities, also being installed, will not only permit of loading and discharge rates of from 1000 to 1500 tons per hour, but result in considerable labour saving and hose wear. Sir William Halcrow and Partners designed and supervised the construction of the wharves for the Shell Petroleum Company, Ltd., and the main problem was to provide structures capable of absorbing the impact of vessels of 60,000 tons displacement. Deep water and a steeply shelving sea bed added to the difficulties to be overcome.

Under the prevailing conditions it was estimated that vessels berthed at a speed ranging from 9in to 12in per second and the structure had to be capable of absorbing the kinetic energy of 60,000-ton vessels moving in at this speed. Two solutions were evolved, one of which was adopted for one of the wharves, the other being applied to the remaining three. In the first solution the dolphins consist of high-tensile steel piles driven deep into the sea bed, braced together at their upper ends and finished with heavy scantling rubbing timbers. Such dolphins can be built comparatively quickly and absorb impact energy by bending, but have the disadvantage of offering only two small isolated berthing faces to the oncoming vessel. The second design consists of a heavy reinforced concrete breasting beam, 240ft in length, carried on a line of forward raking high-tensile steel piles. It is of interest to note that the design included an arrangement whereby the casting of the 1100-ton beam gave the piles an initial forward deflection so that they were prestressed and so of capacity to absorb energy by pile bending. The jetty heads, carrying the hose handling gear, are of independent construction and consist of solid reinforced concrete slabs carried on raking piles, and there are mooring dolphins, of mass concrete on steel piles, designed to withstand mooring rope pulls of 120 tons.

To attain the 1000-1500 tons per hour rate of handling the bulk cargo, up to four 60ft long, 8in bore hoses are necessary and by the use of mechanical handling gear the hose coupling operation has been reduced from two hours, using the ship's derricks, to a half hour. Our photograph shows the hose handling gear and the breasting beam.



Jetty head, mechanical hose handling equipment and breasting beam

Heaters for Storage Drums

THE problem often arises of extracting from storage drums viscous or solidified substances, such as grease, bitumen, or certain chemicals and plastics. Such materials may be melted or rendered more fluid by means of the "Heron" drum heaters, which are now being marketed by Houseman and Thompson, Ltd., D.M. House, Jesmond Road, Newcastle upon Tyne. In addition, the heaters may be used for the quick and complete drying of washed drums.

The standard form is a strongly built sheet metal hood, which can be lowered over a 45-gallon drum. A steel-sheathed heating coil is mounted inside the hood with lagging between the coil and the wall. Any convenient electric supply can be used, and two built-in thermostats control the temperature at any desired value up to 300 deg. Cent. The maximum consumption is 7kW and the maker states that a 400-lb drum of bitumen can be emptied in seven minutes or be completely melted in four hours.

To use the standard heater, headroom of at least 15ft is required, but where this is not available the hinged design illustrated in Fig. 1 may be employed. This is similar to the standard version, but is made in two halves which close round the heater and are locked together by means of clips. The firm also market a base heater, which is 21in in diameter by 3in high and has an element which is cast into the alloy. This heater fits the bottom rim of the drum, and can be used in combination with the hood to speed up the heating

Fig. 1—Hinged heater being closed round the drum by means of clips. The two halves move on castors

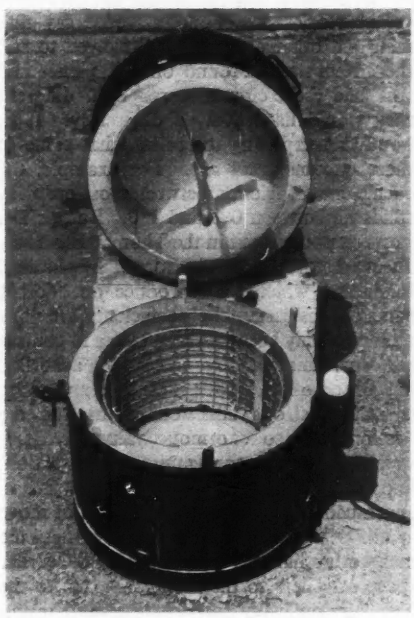


Fig. 2—This heater heats the bottom and sides of the drum up to 300 deg. Cent. A single thermostat is fitted and there is a hand-operated stirrer in the lid

In the "Heron 5" model, shown in Fig. 2, the drum is heated from the bottom as well as the side. A hand-operated stirrer is fitted to the lid and a single thermostat controls the temperature up to 300 deg. Cent. Finally, there is a model which permits drum and heater to be hoisted together.

STAFF LOCATOR SYSTEM.—A new staff locator system for use in offices where noise is undesirable, and workshops where there may be a high level of noise has been introduced by Communication Systems, Ltd., 8, Arundel Street, London, W.C.2. Known as the "Pioneer" staff locator system, it comprises a series of indicators which are automatically illuminated by a control unit to form easily remembered codes. Two kinds of indicators, which each bear three digits, are available—pendant and horizontal for wall mounting—and, with the addition of a star, up to eighty codes are obtainable with the equipment. The pendant indicator is cylindrically shaped, 11in high and 4½in in diameter and shows each of the digits at three points so that they can be seen from any angle. The horizontal indicator is semi-circular and measures 7in wide and 4½in high. The digits are lit internally in each indicator by 15W sign lamps operated from the main supply. All indicators can, if required, be supplemented by an audible alarm.

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FRICTION AND THE FUTURE

A biologist, we suppose, would say that man and other animals have evolved to suit the circumstances found on this planet and that had those circumstances been different they would have evolved differently. It is, however, surprising to realise what some of those circumstances are. For example, the coefficients of friction between most ordinary solids lie between 0·3 and 1·0. But, as Dr. Bowden pointed out in the Thomas Hawksley lecture before the Institution of Mechanical Engineers, which we reproduce on another page of this issue, the coefficients are thus quite low only because the surfaces in contact are contaminated by traces of adsorbed oxygen or other gases ; and under vacuous conditions strong adhesion occurs and the friction rises to enormous values. "If it were not for the contamination we should find the world a very sticky place to live in and much of our machinery would not move at all." We must confess that amongst the many other hazards to be faced by the earlier space travellers to the moon that due to the high friction likely to be experienced on an airless satellite had escaped us ! But the situation would be equally deplorable if coefficients of friction between ordinary solids were normally as low as that of ice. For to a very large extent designers depend upon friction to hold the parts of machines together ; to maintain, for example, the tightness of nuts, or to transmit a drive. Moreover, if he had had to live on slippery surfaces would man ever have dared to develop the upright posture ? So to those other more obvious accidents; the provision, for example, of the right amount of light and the right amount of heat from the sun, the existence of the right amount of water on the surface of the earth and the right amount of oxygen in its atmosphere, not to speak of more subtle things like the appearance of adequate supplies of salt and a proper balance between vegetable and animal life, all of which have contributed to the evolution of man ; we must also add the beneficent accident that the coefficients of friction between most materials are neither too high nor too low, but just about at that level which best suits mankind !

There is, of course, also evolution amongst machines. There, too, the level of common coefficients of friction has had its influence ; and there, too, by learning more about friction we may hope to become capable of evolving new and improved machines. Within that field Dr. Bowden's lecture was illuminated by fascinating side lights. His purpose, of course, was to show what are to-day the limits of scientific knowledge about friction. But repeatedly in listening to the lecture we became aware how closely it touched upon practical problems. With some of the things Dr. Bowden said engineers are already familiar. They have appreciated for many years that when metal surfaces slide upon one another contact only in fact occurs upon numerous very small prominences on the two surfaces and that friction at those points generates sufficient heat to produce local melting. That concept accords well with the observed relationship that friction is proportional to the force holding two surfaces in contact and not to the apparent area of contact. Engineers have, too, been aware that when one metal slides upon another there will be a transference of minute amounts of material from one metal to the other. What, perhaps, has been less well appreciated is that a transference of material can take place from the surface of such a tool as a hammer to the object struck, or from spanners to nuts and bolt heads, and the like. The amount of transference is, of course, very minute. Yet as Dr. Bowden pointed out, there may be an important practical consequence. Such "foreign" material embedded, for example, in a corrosion resistant surface may initiate corrosive attack. In one part of his lecture Dr. Bowden described work with an immediate practical purpose, that of investigating whether fire-damp can be ignited by frictional hot spots, from which it appears that ignition is brought about by flying particles, abraded from the surfaces in contact and not at the rubbing surface itself. Again in another very practical section experiments are described in the use of a "plastic," polytetrafluoroethylene (P.T.F.E.), which has an exceptionally low coefficient of friction, for the under surface of skis. Curiously enough, only a fortnight ago we pointed out how many interesting technical problems arise as soon as new materials begin to be used for the manufacture of sports goods. Here is another example. The low coefficients of friction between other materials and ice occur, not because, as was previously thought, the pressure induces surface melting of the ice, but because the heat generated at the minute points of contact brings about local melting.

In the latter part of his lecture Dr. Bowden turned to study knowledge now being gained that may have practical applications in the future. What, for example, happens to coefficients of friction at very high sliding speeds of the order of 2000 m.p.h. ? That the friction should be found to fall off is by no means unexpected. For even at more normal speeds that effect has been observed. The friction between the tyres of a motor vehicle and the road surface falls off, for example, quite markedly as speed is increased, a condition that adds to the hazards of fast driving. At very high speeds it is found that frictional resistance can be very much less than at ordinary speeds and that the wear per unit of distance slid can also be very much less. But it appears to be another—rather alarming—conclusion that in a really high-speed bearing the load would be carried very largely by a liquefied film of the bearing material ! A problem of more immediate relevance to present-day circumstances is that of running a bearing at a temperature very much higher than the 300 deg. Cent. that is about the present practicable maximum. Experiment shows that here, too, the friction within a lubricated bearing falls away as the temperature is increased, though that conclusion only applies at present to "outgassed" graphite as the lubricant. The coefficient of friction at 2000 deg. Cent. is about one-half of that at normal atmospheric temperature. It is undoubtedly true as Dr. Bowden remarked, that "the engineer would like to run bearings and to slide surfaces at 1000 deg. Cent. and at very high speeds." The experiments indicate not only that it may prove possible to do so, but that there would be positive advantages in so doing, provided that "new and unconventional surfaces and lubricants" are developed. In one other very practical field Dr. Bowden removed a misconception. It is a very natural assumption that the friction observed when a loaded ball is rolled along a groove arises, first, from the fact that a true rolling action can occur only along two particular lines of contact and that elsewhere there must be combined rolling and sliding action ; and secondly, because there must be some flattening of the surfaces in contact under the load, with, similarly, a consequent interfacial slip. But in reality it has been demonstrated "that rolling friction does not generally arise from inter-facial slip, . . . the major part of the rolling resistance comes from hysteresis losses within the metals themselves." In fact, it might be claimed that there should have been no mention of ball bearings in a lecture solely devoted to "Recent Studies of Metallic Friction" !

Obituary

SIR ERNEST LEMON

We record with regret the death of Sir Ernest Lemon, which occurred in London on December 15th, a few days after his seventieth birthday. For over thirty years he was engaged in the mechanical engineering departments of the former London, Midland and Scottish Railway and its predecessors, and for eleven years prior to his retirement from the railway service in 1943 he was a vice-president of the L.M.S. group.

Ernest John Hutchings Lemon was born at Okeford, and studied engineering at the Royal Technical College, Glasgow, and at the Heriot Watt College, Edinburgh. He served an apprenticeship at the Hyde Park Works, Glasgow, of the North British Locomotive Company, Ltd., and when that was completed in 1905 he spent some time in the drawing-office of Brown Brothers and Co., Ltd., Edinburgh. Later, in 1905, Sir Ernest was appointed to the staff of the running department of the Highland Railway. After two years there he joined the staff of Hurst, Nelson and Co., Ltd., where he remained for three years prior to being appointed, in July, 1911, chief wagon inspector of the Midland Railway Company. Subsequently Sir Ernest became works manager of the Midland Railway's carriage works at Derby, and on the grouping of the railways at the beginning of 1923 he was appointed divisional carriage and wagon superintendent of the London, Midland and Scottish—first at Derby and later at Newton Heath. During the four years in which he held those appointments he was responsible for the reorganisation of the carriage and wagon works at both places. Sir Ernest was promoted to the position of carriage and wagon superintendent of the L.M.S. at the beginning of 1927, and in 1931 he was appointed chief mechanical engineer. A year later he was elected vice-president, traffic and commercial, of the L.M.S. group. Sir Ernest took special interest in the matter of staff training, and it was through his efforts that the school of transport was established at Derby by the L.M.S. Company.

In 1938, Sir Ernest's services were lent to the Air Ministry, where he became director-general of production and a member of the Air Council. In recognition of his work for the Air Ministry in the early part of the second world war he received his knighthood. Sir Ernest resumed his duties with the L.M.S. towards the end of 1940, and two years later was transferred to the Ministry of Production to carry out some special work associated with the war effort. He retired from the L.M.S. early in 1943, and about the same time took up the chairmanship of a commission which was appointed to consider the post-war planning of the railways. Another important appointment which Sir Ernest took after his retirement from the L.M.S. was the chairmanship of the Committee for Standardisation of Engineering Products, which was set up by the Minister of Supply in November, 1948. The report of that committee was presented less than a year later, one of the main recommendations being that the production of national standards of wide applicability should be extended and speeded up. To that end, the committee suggested, all sections of industry should urge forward the work of the British Standards Institution. When the Lemon committee, as it came to be known, had completed its task and drafted its report, Sir Ernest was appointed to another committee, set up by the President of the Board of Trade, to consider the organisation and constitution of the British Standards Institution. During the early stages of the work of that committee, Sir Ernest gave valuable help, although, owing to other commitments, he felt obliged to retire from it before its task was concluded. Sir Ernest was a member of the Institution of Mechanical Engineers, a member of the Institute of Transport, and a past-president of the Institution of Production Engineers.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

SKIN PLATING ON STEEL GATES

Sir,—We are interested in Dr. Leliavsky's article on "Skin Plating on Steel Gates" (published in The Engineer of October 8th and 15th), being ourselves engaged on research work on the stress analysis of dock and sluice gates. Dr. Leliavsky has confined his attention to the design of the skin plating, but in our view it is doubtful whether this element can be considered in isolation from the main structure of the gate to which it must be securely attached and with which it must deform.

There would appear to be two ways of considering the stressing of the skin plate :—(*a*) assuming that it forms an integral part of the main structure and acts as a flange plate to the main members ; or (*b*) assuming that its function is merely to transmit the water pressure to the main members without contributing to their flexural strength. If one proceeds on the first assumption it is logical that the thickness of the plating should increase with the span. With the thickness of plating commonly employed it would appear that this assumption would have to be made in order to secure economy of design ; in this case, local bending of the skin plating, as discussed by Dr. Leliavsky, would be considered as a secondary effect. If, on the other hand, the skin plating is not to contribute to the strength of the main members it would then be correct to design the panels as diaphragms and, as Dr. Leliavsky implies, a great reduction in the thickness of the skin plating should be possible. Whether very thin skin plating would be desirable on practical grounds is, however, open to doubt. Further, as Dr. Leliavsky has shown, the formulæ available for designing plating are not entirely satisfactory, and there is the further complication, not mentioned by him, that the edges of the panels are not secured to a rigid foundation but to the main members of the gate ; as these deflect the boundary geometry alters and the stresses and deflections of the panels are modified.

We would suggest, therefore, that the first approach presents the most promising basis for a design method, and our research has in fact been proceeding on the assumption that the skin plating is an integral part of the main structure.

Arnold W. Hendry, D.Sc.
S. R. Lamond, B.Sc. (Eng.)

University College of Khartoum.
December 8th.

SAFE WORKING LOADS OF ROPE BLOCKS

Sir,—The letter from Mr. G. H. Boot, appearing in your issue of November 12th, criticises British Standard 1839, "London Pattern Pulley Blocks," and suggests that it is in need of amendment. This British Standard relates to single, two-sheave and three-sheave pulley blocks and specifies, amongst other requirements, the appropriate safe working loads and proof loads applicable to such blocks ; a table of these loads was reproduced in The Engineer. The standard does not deal with tackles, as a given block will be subjected to different loading conditions according to the arrangement of the blocks in the tackle, and such design data are outside the scope of the present standard. The requirements of B.S. 1839, so far as proof loading and the marking of safe working loads are concerned, are directly comparable with those given in B.S. 408, "Ships' Cargo Lifting Blocks," which in turn was based on the requirements of the Statutory Docks Regulations, 1934, a Code of Regulations having an international background.

Although the question of the arrangement of tackles is therefore outside the scope of B.S. 1839, perhaps I may be allowed to make one or two comments on two points raised by Mr. Boot. Taking as a basis the fact that the upper and lower blocks in a tackle are of the same nominal size, appropriate to the circumference of the rope used, it will be observed on referring to his drawing that :—

(*a*) Whilst the lower block presumably marked "S.W.L.=1" (proof load=4) could safely be used to support a load of 2 (as shown), the resultant load being one-half of the proof load, it will be appreciated that an exactly similar block at the top is subjected to a resultant load of three, in which case the proof load is only 33⅓ per cent in excess of this resultant load to which the hook is subjected. When using a pair of identical single-sheave blocks a load of twice the safe working load, which is marked on either block, should not be lifted.

(*b*) When, however, a single-sheave block is used with a double block (of the same nominal size), and again referring to the table in The Engineer, due to the increased strength of the double block at the top, it is practicable to use the bottom single-sheave block for a load of twice the safe working load marked on it (as permitted by Docks Regulations, 33 (*a*)).

Since the becket on this single-sheave block will under these conditions be subjected to a greater load than that in case (*a*), the proof load to be applied to this becket should be as stated in the standard and not as advocated by Mr. Boot.

The B.S.I. Committee responsible for drafting B.S. 1839 includes representatives of manufacturers, users and testers of this equipment, and of Government departments such as the Factories Department of the Ministry of Labour. The points raised by Mr. Boot have received careful study and it is not considered that any amendment to the standard is necessary.

G. Weston

Technical Director,
British Standards Institution, London,
December 8th.

Tabular Summary of Civil Engineering Contracts

Our annual supplement of civil engineering contracts, for the year 1954, is published with this issue of The Engineer. The supplement includes civil engineering contracts valued at £50,000 or over (in some sections the limit is £100,000) which were in progress during 1954, or which were due to be let by the end of the year. The contracts are listed under the headings of : airports; coast protection; district heating; drainage and sewage works; harbours and docks; hydro-electric works; irrigation; power stations; railways; rivers and waterways; roads, steelworks; structural and industrial; and water supply.

Books Received

Massbalancing of Aircraft Control Surfaces. By H. Templeton. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 35s.

The Physics of Particle Size Analysis. A conference arranged by the Institute of Physics and held in the University of Nottingham from April 6 to 9, 1954. London : The Institute of Physics, 47, Belgrave Square, S.W.1 Price 35s.

Engineering Dynamics : Vol. III, *Steam Turbines.* By C. B. Biezeno and R. Grammel. Vol. IV, *Internal Combustion Engines.* By C. B. Biezeno and R. Grammel. Glasgow : Blackie and Son, Ltd., 17, Stanhope Street, C.4. Price, Vol. III, 40s.; Vol. IV, 50s.

Recent Studies of Metallic Friction

By F. P. BOWDEN, Sc.D., D.Sc., F.R.S.*

No. I

In the Thomas Hawksley Lecture delivered before the Institution of Mechanical Engineers last Friday, Dr. Bowden reviewed existing scientific knowledge about friction. After discussing friction between metallic surfaces he turned to study non-metallic solids. As a practical matter of interest to engineers he considered ignition of firedamp due to frictional hot spots and hot metal particles.

THE first thing one observes, of course, if one attempts to slide one solid over another is that there is a resistance to the motion, which is called friction. Experiment has shown that this frictional resistance obeys two well-known laws. The first of them says that the friction is independent of the size of the surfaces in contact, and the second that it is proportional to the load.

Nature and Area of Contact of Solid Surfaces : Mechanism of Friction

Now what is the explanation of these laws and what is the cause of this friction ? The first step must be to examine the nature of a solid surface and in particular its topography and surface contour. To do this we have been using a variety of physical methods which include stylus methods, taper sectioning, multiple-beam interferometry, the electron microscope (both in transmission and in reflection), and electron diffraction. The more carefully one examines solid surfaces, the more clearly one sees that they are never flat.† Even with modern techniques of polishing it is difficult to prepare surfaces of appreciable size that are flat to within 100–1000Å. Most of the surfaces used in engineering practice have surface irregularities which are very much greater than this. When therefore two solids are put together, the top surface will be supported on the summit of the highest irregularities and the area in intimate contact will be small. Detailed measurements show that the area is indeed very small; it varies with the load, but for flat steel surfaces it may be less than one ten-thousandth of the apparent area (Bowden and Tabor, 1950).

The experiments are also interesting in that they show that the real area of contact is almost independent of the size of the surface. It is also very little influenced by the shape and degree of roughness of the surfaces ; it depends mainly on the load which is applied to them, and is in fact directly proportional to the load. The general behaviour is consistent with the view that the surfaces are held apart by small irregularities. This means that, even with lightly loaded surfaces, the local pressure at these small points of contact is very high and may be sufficiently great to cause the hardest metals to flow plastically. Although the stresses will cause elastic deformation of the metal in the vicinity of the points of contact, the experiments suggest that the summits of irregularities on which the bodies are supported flow plastically and are crushed down until their cross-section is sufficient to enable them to support the applied load. The real area of contact A is given by $A=W/p_m$, where p_m is the yield pressure of the metal.

The fact that the real area of contact is so small has important practical implications. Even when loads of only a few grammes are applied to the surfaces, the local pressure between them may be sufficiently great to cause the flow of metal. When large flat surfaces are used, it does not mean that the real pressure is much less, but merely that the points of contact are more widely distributed. This intense pressure will cause adhesion or "pressure welding" at the tiny points of contact and so produce small metallic junctions between the surfaces. There is strong evidence that the friction of metals is due, in a large measure, to these localised adhesions and represents the force necessary to shear these small junctions. As a rough approximation one may therefore write $F=As$, where s is the shear strength of the junctions.

One sees that this picture offers a simple explanation of the two laws of friction. First, since A, the real area of intimate contact, is independent of the size of the surfaces, the friction will be independent of this. Secondly, since the real area of contact A is proportional to the load, the friction will be also. If the friction is proportional to the load it means, of course, that the coefficient of friction $\mu=F/W$ is a constant. For the above reasons one may expect the friction of most metals (and indeed of most plastic solids) to have a similar value, a soft solid gives a large A value but a small s value, and a hard solid a small A value but a large s value. On occasion the shearing may occur at the interface, but more frequently (because of work hardening of the contact region) it occurs a little distance beyond it. A metal fragment is detached from one of the surfaces and adheres to the other. The transfer can occur from a hard metal to a soft one as well as conversely.

I should like to emphasise that the coefficient of friction which one normally observes between metal surfaces (μ equals about 0·3 to about 1) is due essentially to the presence on their surface of films of oxide or adsorbed gas. If the metals are put in a high vacuum and these surface films taken off, one finds that one cannot slide the metals at all. The metallic junctions grow to a large size, the friction rises to a very high value and gross seizure occurs. It is only when air is admitted that the friction falls to its usual value.

Metallic Transfer in Engineering Operations

The phenomenon of metal transfer is of some importance to mechanical engineers, for in practically all engineering operations metal tools are brought into contact with the surface of the product. One may expect that some metallic transfer will occur, and it is very probable that the finished product will have small fragments of the tools used in its manufacture permanently embedded in its surface. Radioactive tracer technique has been found to be a very powerful method of detecting and measuring these small fragments. Recently, in collaboration with Mr. J. B. P. Williamson, we have been studying the transfer which occurs in several common engineering operations and he has measured the amount of metal from the tool which becomes transferred to the handled object (Bowden, Williamson and Laing, 1954).

For each operation studied, the part of the tool which came in contact with the product was previously irradiated in the neutron pile at Harwell and the radioactive fragments of it left on the surface were measured by means of either a Geiger counter or a scintillation counter. All the tools used in these experiments were made of normal high-speed tool steel, and, for our purpose, only the activity acquired by the tungsten in them was significant.

[Particulars were then given of transfer to an object clamped in a vice, from hammers, from riveters, from screwdrivers, from spanners, from twist drills and from lathe bits.]

Methods of Reducing Transfer.—There are several ways in which unwanted transfer may be reduced. One of the simplest is lubrication, since the oil diminishes the amount of metallic contact and hinders the growth of the junctions. Another is by avoiding, as far as possible, any slip between the surfaces. The results quoted for the amount of transfer in various engineering operations illustrate these general effects.

In normal circumstances fragments are plucked out of both metals and transferred to the other surface ; but by controlling the relative hardness of the contacting surfaces the transfer can be made to go predominantly in one direction. Table I shows the effect of altering the hardness of the surfaces on the transfer from a screwdriver to a stainless steel screw. The drivers and screws used in this experiment were samples of those made for use by orthopædic surgeons. The transfer in the condition in which the tools are normally supplied has been taken as unity ; it is clear that the amount may be reduced either by softening the screw or by hardening the tool.

TABLE I.—*Dependence of the Relative Amount of Transfer on the Hardnesses of Drivers and Screws*

	Steel driver of 150 Vickers hardness number	Steel driver of 360 Vickers hardness number
Steel screw of 380 Vickers hardness number	1	1/10
Steel screw of 133 Vickers hardness number	1	1/10

Apart altogether from the relative hardness, the metallic transfer is very specific and depends upon the detailed structure of the metal and the nature of the oxide layer.

Significance of Metallic Transfer.—These experiments have shown that appreciable amounts of the engineering tools used to make a product become transferred and permanently attached to its surface. This occurs most markedly under non-lubricated conditions, and where great force is used and slip occurs. It is detectable even when the tool is many times harder than the metal object and when there is little or no slip.

Although the amounts of transfer are very small they may in certain special circumstances be detrimental merely as an impurity. For example, in the production of spectroscopically pure metals, the transfer from the tools used to shape the analysed metal may seriously impair the purity of the finished product. However, the effect of these particles is not necessarily limited to the transferred fragment only. In certain circumstances these particles of a foreign metal may initiate a continuing damage very much more important than the apparent significance of the tiny fragment itself. Most metals owe their resistance to chemical attack to the layer of oxide on their surfaces. There is evidence that the transferred particles penetrate this oxide layer and adhere to the

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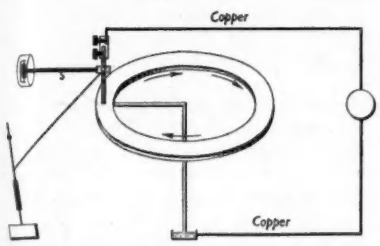
† Recently Dr. Anita Bailey and Dr. J. S. Courtney-Pratt (1954) have studied the behaviour of molecularly flat surfaces in contact. Their behaviour is quite different from that of ordinary solids and the usual "laws" of friction are no longer obeyed.

underlying metal. The presence of a particle of a foreign metal, however small, may start a local electrochemical corrosion and cause a break in the protective oxide layer. This can lead to large-scale continuing corrosion, particularly if the metal is in an adverse environment. If the metal component is subjected to permanent or transient stresses, local corrosion cracks may cause harmful stress concentrations. It is also conceivable that these transferred metal fragments may play some part in fatigue.

Metal transfer may be particularly important in orthopædic surgery, where it



The thermal electromotive force between two different rubbing metals is recorded.

Fig. 1—First method for measuring surface temperature

is common to repair a fractured bone by inserting a metal splint into the patient's body. The splint is screwed or bolted to the bone and may be left permanently in position. Great care is taken that all metal inserted in the body has a very high corrosion resistance. Different metals in contact are not permitted because of possible electrolytic action. Nevertheless, the reaction of the tissues surrounding the buried metal is not always satisfactory. They frequently become inflamed and tender even when there is no obvious corrosion of the metal. There is some evidence that the metal transferred from the tools (which are not stainless) may contribute to this adverse tissue reaction. It may be advisable for the surgeon to select his tools with the same care that he uses in selecting the buried metal.

Friction of Non-Metallic Solids and Development of Low-Friction Surfaces

I have been discussing mainly the friction of metals but there is evidence that the friction of non-metals is very similar. An account of some of the work which the Laboratory for the Physics and Chemistry of Surfaces, at Cambridge, has been doing on these non-metallic solids has been given in a Redwood Lecture (Bowden, 1954). Again the friction is due mainly to the localised adhesion occurring at the small regions of contact and represents the force required to shear these junctions. The coefficient of friction is much the same. I should like to mention briefly the behaviour of some special solids and the development of some special low-friction surfaces which may be of some practical interest and importance.

Molybdenum disulphide is a solid which has quite interesting frictional properties. It has a laminar plate-like structure rather like graphite and can give a low friction. It is normally used in the form of a fine black powder which is welded on to a steel surface. Since it is only loosely attached to the surface it may easily wear away. Instead of using a steel surface we have tried the experiment of using a molybdenum one and attacking it chemically so as to form the molybdenum disulphide *in situ* (Bowden, 1950b). It is then firmly attached and, if the molybdenum is porous, it may penetrate to a considerable depth beneath the surface. Such surfaces can be heated and experiment shows that when running red hot the coefficient of friction is still only 0·07 and is less than that of a well-oiled steel surface.

Some other studies we have been making which have proved interesting are on the frictional behaviour of some of the new "plastic" materials (Shooter and Thomas, 1949). These polymerised plastic materials often consist mainly of carbon and hydrogen with the molecules arranged in long strings. One of the simplest of these is polythene or polyethylene which consists of a long string of carbon atoms with hydrogen atoms attached. If all the hydrogen atoms are removed and replaced with chlorine one has a new plastic called polytetrafluoroethylene (P.T.F.E.). This material has remarkable surface properties and exhibits very low frictional characteristics.

Typical values of friction for a number of plastic materials are given in Table II.

Table II.—*Friction of Plastics*

Plastics	Coefficient of friction, μ
Polyvinyl chloride (P.V.C.)	0·4–0·5
Polymethyl methacrylate (Perspex)	0·4–0·5
Polystyrene	0·4–0·5
Nylon	0·3
Polyethylene (Polythene)	0·5–0·8
Polytetrafluoroethylene (P.T.F.E.)	0·05–0·1

It will be seen that P.T.F.E. has an exceptionally low coefficient of friction. This low friction appears to be characteristic of the material itself, since even in a high vacuum, when extraneous surface films are removed, one finds that the friction remains low. It clearly has very desirable frictional properties. We have studied its frictional behaviour when it is incorporated in a porous metal such as sintered copper (Bowden, 1950a). In this way one has a material which possesses the mechanical and thermal properties of sintered copper but has the frictional properties of the plastic, since this is present as a thin film on its surface. Some typical values at different temperatures are given in Table III. This

Table III.—*Coefficient of Friction of Metal Impregnated with P.T.F.E.*

Temperature, deg. Cent.	Coefficient of friction, μ	
	Copper	Impregnated copper
15	About 1·0	0·05
100	About 1·0	0·05
200	About 1·0	0·05
250	Greater than 1·0	0·05

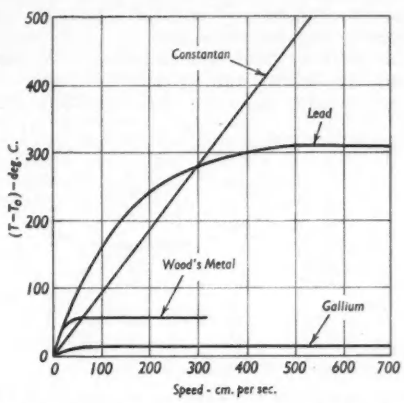
combination gives a very low friction (μ= 0·05), which is lower than the friction of a well-lubricated surface, and maintains its properties up to high temperatures. It is already proving to be in practice a useful low-friction material. I shall say a little more about the behaviour of P.T.F.E. when I discuss the mechanism of skiing.

Surface Temperature of Sliding Solids

We have seen that the real area of contact between solids is very small, and this has a second important consequence. The energy lost during sliding is dissipated mainly in the form of heat, and quite primitive calculations of the amount of heat which is liberated and of the rate at which it is conducted away suggest that the temperature rise of the surface layers may be high. If one endeavours to measure this by embedding thermometers in the solids, near the surface, it is found that the rise is very small, but this is mainly because it is not possible to get close enough to the interface.

(1) *Thermoelectric Method.*—An obvious method is to use the surfaces themselves as a thermometer ; this may be done (Bowden and Ridler, 1936) by sliding two different metals together and measuring the thermoelectric potential which is developed (Fig. 1). It is apparent that the electrical contact and the friction occur at the same points where the surfaces touch, so that the measurement gives information about the temperature of the surface layer of the metals where they are rubbing.

Such measurements confirm in a very striking way the existence of local high temperatures at the points of contact of the rubbing surfaces. As would be expected, the temperatures reached depend upon the load, the speed of sliding and the heat

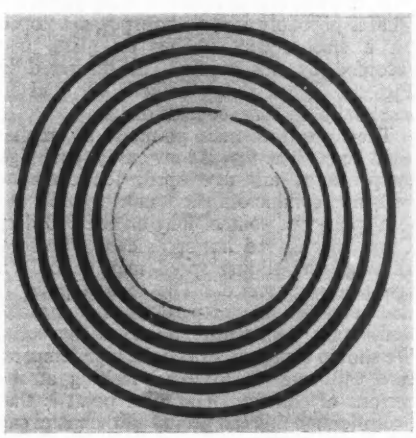


Load 100 grammes ; the temperature does not exceed the melting point of the metals

Fig. 2—Maximum temperatures reached when small cylinders of gallium, Wood's metal, lead, and Constantan are slid on a steel surface

conductivity of the metals. Also, the temperatures fluctuate very rapidly during sliding, and it is necessary to use an instrument of high frequency, such as a cathode-ray oscillograph, to record them.

It is found that with the lower melting point metals their melting points are readily reached, and the temperature does not rise above this (Fig. 2). If the actual rubbing surfaces are oxide and the melting point is high, the temperatures reached may, of course, be very much greater. With metals of high melting points, momentary temperatures of from 500 deg. to 1000 deg. Cent. are easily reached. These temperatures are confined to the very thin surface layer, and the mass of the metal appears to be quite cool. These



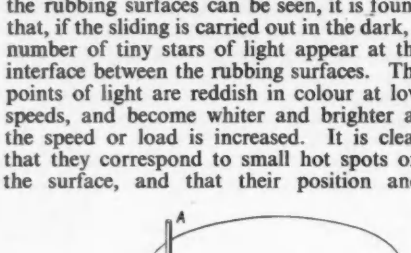
The hot spots are observed visually or recorded on a photographic plate ; load, 1200 grammes ; speed of sliding at innermost visible track, 70cm per second, approximately.

Fig. 3—Second method for measuring surface temperature

very high-temperature flashes of 1000 deg. Cent. may last only for a few ten-thousandths of a second.

(2) *Visual or Photographic Method.*—If one slides non-metals such as wood or glass which are bad thermal conductors one would expect the temperature rise to be still higher. It is not possible, of course, to use this ther-

moelectric method to measure the temperature. One may, however, use other methods ; one of them is a visual method (Bowden) Stone, and Tudor, 1947). If polished surfaces of glass or quartz are used, and the apparatus is so arranged that a clear image of the rubbing surfaces can be seen, it is found that, if the sliding is carried out in the dark, a number of tiny stars of light appear at the interface between the rubbing surfaces. The points of light are reddish in colour at low speeds, and become whiter and brighter as the speed or load is increased. It is clear that they correspond to small hot spots on the surface, and that their position and



Heat radiation from hot spots on the end of the cylinder *A* is transmitted through the transparent solid *B* and recorded on the infra-red sensitive cell *C* ; *D* is a chopper.

Fig. 4—Third method for measuring surface temperature

distribution over the surface change from instant to instant as the high points in intimate contact move or wear away, and as new points come into contact. These hot spots can also be photographed in a very simple way ; if a photographic plate is placed on a turn-table with the glass side upward and allowed to rotate with a metal slider resting on it, the luminous hot spots developed at the points of rubbing contact will photograph themselves on the emulsion (Fig. 3).

(3) *Infra-red Cell Method.*—The third method (Bowden and Thomas, 1954) which we have found revealing is to use a lead sulphide cell, which is sensitive to infra-red radiation and which has a very rapid response. If one of the solids is transparent, say, glass or quartz, the radiation from the hot spot may be transmitted through it and measured. The experimental arrangement is shown in Fig. 4. The rise and fall in temperature of what is probably a single hot spot, developed on a steel slider rubbing on glass, and recorded by this method, is illustrated in Fig. 5. These three methods all lead to essentially the same conclusions.

There are three main points to be emphasised here. The first is how easily local high temperatures are developed, for example, with non-conductors the temperature at the local points of contact may exceed 500 deg. Cent., that is, red hot spots can be formed although the sliding speed may be only a few feet per second. The second point is that the rise in temperature is normally limited by the melting point of the solid. We should expect this since the high temperature will cause a localised melting at the regions of contact. The third point is that exceptions to this can occur. If the metal can be readily oxidised and if this oxidation is an exothermal process, for example, aluminium and magnesium, the hot-spot temperature may be very much higher because of the heat of oxidation liberated at the oxidising surface. It is, of course, no longer limited by the melting point of the metal and very high temperatures indeed may be reached—perhaps 2000 deg. Cent. or more. As will be seen later this can occur if a metal fragment is detached from the surface.

These local hot spots are important in a number of physical processes associated with the rubbing of solids. They are, for example, very important with polishing and we have found strong evidence that the formation of the polished, or Beilby, layer on metals and other solids when they are rubbed, is due to a localised melting or high-temperature softening of the solid at the points of rubbing contact. The melted or softened solid is smeared over the surface, bridging and filling up the surface scratches. It is quickly cooled to form the micro-crystalline or "amorphous" Beilby layer. We have also found that they play a major part in causing initiation of explosions in solids and liquids when they are subjected to friction or to impact.

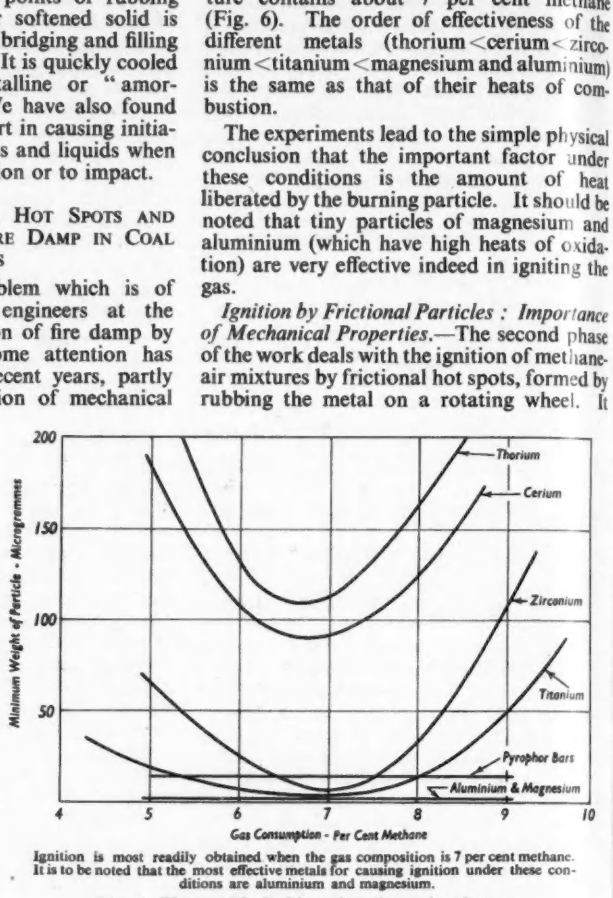
Ignition by Frictional Hot Spots and Metal Particles of Fire Damp in Coal Mines

Another practical problem which is of interest to mechanical engineers at the present time is the ignition of fire damp by frictional hot spots. Some attention has been focused on this in recent years, partly because of the introduction of mechanical methods into coal mining, and partly because of the use of aluminium and magnesium alloys in the manufacture of pit props. It has been well known for a long time that fire damp could be ignited by frictional sparks and an interesting review of this has been given (Wynn, 1952). We are collaborating with the Safety in Mines Research Establishment in an examination of this problem and Mr. R. D. Lewis has been studying the mechanism of the ignition of methane-air mixtures by frictional particles.

Ignition by Stationary Particles.—The work has fallen into two main parts. For the ignition by stationary metal particles a study is made of the minimum size of particle which will ignite the gas. It is shown that if they are heated to their ignition point very small particles can be effective in exploding the gas (less than 1 microgramme for aluminium and magnesium). The minimum size of particle is dependent on the composition of the gas. Ignition is most readily obtained when the methane-air mixture contains about 7 per cent methane (Fig. 6). The order of effectiveness of the different metals (thorium < cerium < zirconium < titanium < magnesium and aluminium) is the same as that of their heats of combustion.

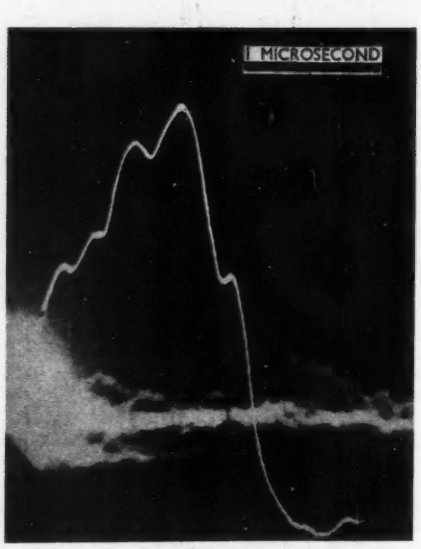
The experiments lead to the simple physical conclusion that the important factor under these conditions is the amount of heat liberated by the burning particle. It should be noted that tiny particles of magnesium and aluminium (which have high heats of oxidation) are very effective indeed in igniting the gas.

Ignition by Frictional Particles : Importance of Mechanical Properties.—The second phase of the work deals with the ignition of methane-air mixtures by frictional hot spots, formed by rubbing the metal on a rotating wheel. It is found that ignition can be obtained in this way and the effect of load, speed and nature of the metal on the ignition has been investigated. With a metal like zirconium, ignition can be obtained at rubbing speeds of 5m per second and loads of about 500g. Ignitions occur more readily if the load and the speed are increased. At very low loads and speeds ignition does not occur. The order of effectiveness is quite different from that observed with stationary particles. It no longer depends on their heat of combustion. Under the conditions of these experiments no ignitions were obtained with aluminium, magnesium, or their alloys.



Ignition is most readily obtained when the gas composition is 7 per cent methane. It is to be noted that the most effective metals for causing ignition under these conditions are aluminium and magnesium.

Fig. 6—Hot-particle ignition of methane-air mixtures



Duration about 2 microseconds ; load, 350 grammes ; speed of sliding, 700cm per second.

Fig. 5—Radiant energy received from a single hot spot developed between a steel slider and rotating glass disc

There is strong evidence that an important factor here is the mechanism of wear or break-up of the metal when it is rubbed. The particles of metal which were abraded from the rubbing surfaces and projected into the gas were captured and examined microscopically. The rubbing metal surfaces were also examined in a similar way. It was found that with the effective metals, such as zirconium and pyrophor (the metal used for lighter flints) small metal particles are detached. For zirconium the larger particles were about 0·5mm in diameter (110 microgrammes). For pyrophor they were 0·3mm in diameter (50 microgrammes). With titanium, ignitions were not obtained and the detached particles were small (0·3–0·6mm in diameter, that is, 2–10 milligrammes). These particles, however, did not burn on leaving the surface. With the other non-effective metals, that is, magnesium, aluminium and their alloys, no

flying particles were detected. The rubbing metal was plastically deformed and smeared over the sliding surface.

It is clear that ignition is brought about by the flying particles and not by the rubbing surface itself. In this frictional ignition the "brittleness" and the mechanical properties of the solids are of primary importance since these determine the size of the particles supplied. The method of disintegration and the rate of burning of the particle can also be important. It was noted that with pyrophor the metal particles did not burn as a whole, but disintegrated into a number of widely dispersed burning sparks. This material is more effective in causing ignition over a wide range of gas composition.

It is interesting to note that with zirconium the size of the flying particle which can cause ignition is appreciably greater than that of the stationary particle. This is probably due to the shorter time of contact with the gas and the greater thermal losses of the moving particle.

Ignition by the impacting metals occurs less readily, partly because the local temperatures reached are not so high, and partly because small metallic fragments are not so readily detached. A detailed study of the way in which the metal particles burn, disintegrate and ignite the gas is being made with the aid of Dr. Courtney-Pratt's new high-speed cine-microscope camera. This camera which has been described elsewhere (Courtney-Pratt, 1953) provides a new and powerful tool for the study of rapid physical processes and fast moving objects. It should, I think, prove of assistance to mechanical engineers on a number of their high-speed problems.

One sees that these frictional hot spots may be a nuisance in the mining industry, but they can also be helpful. I hope to show that it is in fact this surface heating which makes it possible for people to indulge in winter sports and skiing.

(To be concluded)

Productivity, Fuel Availability and Its Efficient Use

By K. T. SPENCER

No. I

All industrial production depends decisively on fuel and power. British industry grew up and became a leading influence in the world in an age of cheap and abundant coal. So far as we in this country are concerned, that cheapness and that abundance have gone for ever. Atomic energy may falsify this prophecy. But as yet we cannot count on its doing so soon. We must face up to a continuing fuel shortage over many years. This paper, one of those presented at a D.S.I.R. Conference on Research and Industrial Productivity, held from November 22nd to 25th, gives facts about the present fuel and power situation and how that situation has come about during the last generation or two. The facts are well-documented, but even now they are not widely enough realised.

How the Present Situation has Developed

Britain's first recorded fuel crisis occurred in the sixteenth century. Although coal had been mined in small quantities since at least the fourteenth century and some power was obtained from windmills and waterwheels, the general fuel at this time was still wood.

According to Trevelyan,[1] the sixteenth century was notable for a great expansion of mining of all kinds. In the smelting of the ores, particularly iron ores, vast quantities of wood and charcoal were burned and the timber resources of the country were drained away. Household heating and cooking depended normally on wood, as did the manufacturing industries, and, as local supplies became exhausted, we are told that many a cottager had a cold hearth and a bread-and-cheese diet and the output of the manufacturers was sorely restricted. Some works, including those of the new glass industry, had to move around and follow the woods. It was during the period of 1550 to 1600 that coal started to come into much greater use to supply the deficiencies, though this was limited to localities near to the pits or near to navigable water. In 1578 it was said that "brewers, dyers, hat-makers and others have long since altered their furnaces and fiery places and turned the same to the use and burning of sea-coal." A premature and unsuccessful attempt was also made at this time to smelt iron with coal.

During the period 1750–1800, in return for manufactured goods, the North American colonies sent us timber and pig iron. Timber and iron were also imported from the Scandinavian and Baltic countries because eighteenth century England, having exhausted its natural forests, was short of timber for shipbuilding, house building and fuel. Although coal was now largely filling the fuel deficiency for domestic heating and many manufactures, it was only beginning to be applied on a large scale to the smelting of iron. "And so, in spite of England's potential wealth in iron ore, much iron was imported from lands which still had virgin forests to burn."

The development of the industrial revolution is familiar history. It is sufficiently well-known that, with the application of coke to the smelting of iron, and the rapid expansion of the iron industry and industrial activity generally which followed, there was a sharp rise in the consumption of coal, reaching a pre-war maximum in this country of 200 million tons in 1916. At the same time, up to the commencement of World War I, coal was exported in ever-increasing quantities, reaching a maximum of 98,000,000 tons in 1913.

As was recently shown by Robinson,[2] the effect of industrialisation was gradually to alter the entire economy of the country from self-sufficiency to extensive reliance on imported food and raw materials. At the present time, 50 per cent of our food is obtained from abroad and we have come to depend more and more on the importation of raw materials, not only to satisfy the needs of a much bigger population, but also because many native resources, for example, lead, tin, copper and timber, have been virtually exhausted.

Manufactured goods have therefore to be exported in ever-increasing quantity, in the face of growing competition from the more recently industrialised countries, particularly the U.S.A., whose manufacturing capacity and resources of raw materials and energy are vastly greater than our own.

In order to survive at all, the flow of manufactured goods has to be maintained and increased and we have only one indigenous resource with which to provide the energy required by the manufacturing industries. But coal production has not kept pace with the growing needs of our factories. Thus we are again approaching a situation similar to that of the sixteenth century.

Trends of Energy Consumption in Great Britain and Elsewhere

Apart from the fluctuations caused by two World Wars, the total consumption of energy (coal and its equivalent in petroleum and hydro-electricity) per head of population in Great Britain has remained relatively static for fifty years or more (Fig. 1). Coal consumption has varied around 4 tons per head and, in recent years, this has been supplemented to some extent by imported petroleum, the consumption of which in 1953 had risen to the equivalent of 0·5 tons of coal per head. Hydro-electricity, although of great value to the localities in which it is generated, does not significantly add to the country's energy resources, since it amounts at present to the equivalent of only 1,000,000 tons of coal per annum, or 0·02 tons per head. Even if all potential hydro-electric power resources were fully developed they would represent the equivalent of only 4,000,000 tons of coal per annum. The marginal energy resources, which are at present being investigated and developed, i.e. peat, wind power, methane from mines and, possibly, natural gas, cannot appreciably alter the general picture. This implies that we depend on coal and, unless natural gas is found in large quantities, we will continue to depend on it.

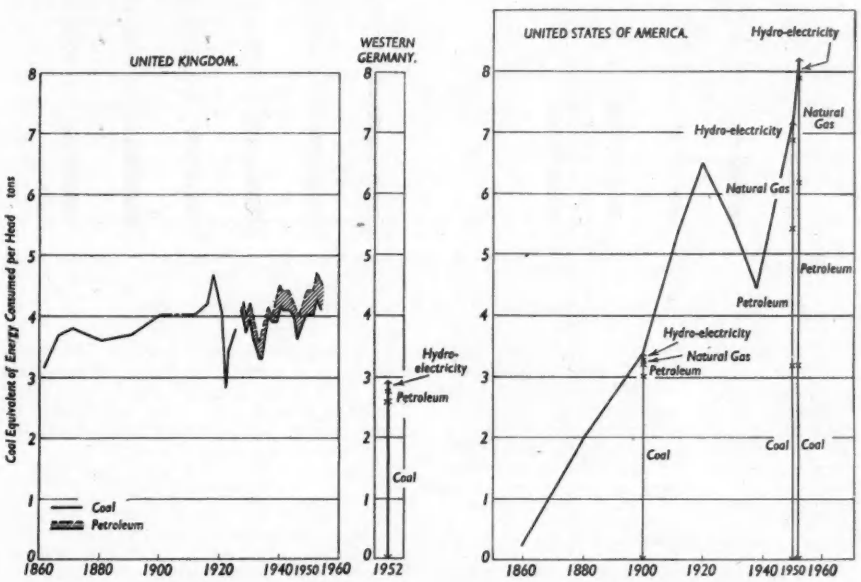


Fig. 1—Energy consumption per head of population in the U.K., U.S.A. and Western Germany

Although our total use of energy has not greatly changed over many years, the pattern of its utilisation has substantially altered. As industrialisation has proceeded apace, the coal requirements of industry have steadily grown (Fig. 2) and, with coal production declining, these requirements have been met so far by increasing efficiency of utilisation, by reducing exports and by increasing the use of oil.

The trend in the utilisation of energy in the U.S.A. has been strikingly different from that in the U.K. (Fig. 1). Apart from wood, for which the facts are not readily available, energy consumption in the U.S.A. in terms of coal per head was, in 1860, only 7 per cent of that in the U.K. By 1950 the corresponding figure had risen to 168 per cent and to-day it is higher, largely as a result of the rapid growth of the natural gas industry, which in 1953 supplied 26 per cent of all the energy requirements of the U.S.A.

A high rate of energy consumption is the main factor in the rapid emergence of the U.S.A. as the leading industrial nation and its high standard of living. Whether this is in the long-term interests of the U.S.A. is open to doubt,

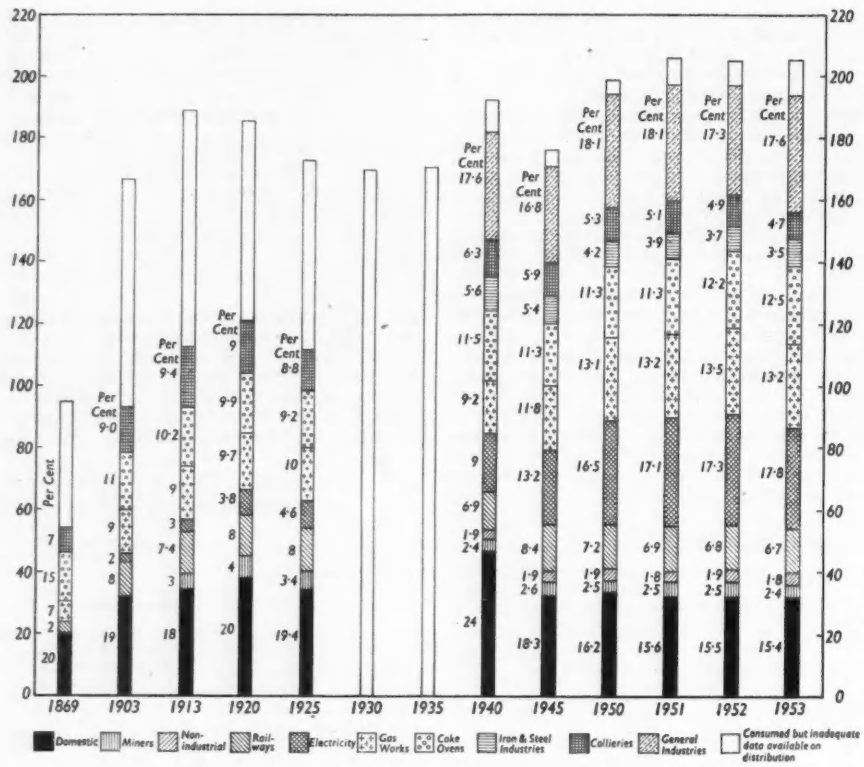


Fig. 2—Inland consumption of coal in Great Britain, in millions of tons

but it nevertheless determines the level of industrial production with which we must compete.

Amongst the European countries, Great Britain is still the largest consumer of coal per head. In the case of Western Germany, which may be quoted for comparison, energy consumption in 1952 was equivalent to just under 3 tons of coal per head, or 68 per cent of the U.K. figure (Fig. 1).

Energy Requirements in the Immediate Future

Although the coal reserves of Great Britain are believed to be enough for at least the next two hundred years, coal is no longer being produced in the quantities needed.

The National Coal Board, in drawing up its plan for reconstruction of the industry, originally estimated that by 1965 the total inland demand for coal would be 205–215 million tons a year and the export demand 25–35,000,000 tons. Therefore, the plan aimed to increase total production to 240 million tons in 1960–65. Later the Ridley Committee made an independent estimate of probable coal requirements. On the basis of past trends in all branches of coal utilisation and making allowance for improved efficiency in utilisation, the committee estimated that in the period 1959–63 the inland demand for coal would probably be some 230 million tons per annum, roughly 20,000,000 tons greater than the National Coal Board figure. In the light of the Ridley Committee's estimate the coal production plan was revised, and the aim is now to produce 260 million tons annually in the period 1961–65.[3]

In the last three years, despite continued restrictions on domestic coal, inland consumption of coal has been running at more than 200 million tons. In the current year 4,000,000 tons are to be imported as a precautionary measure, since it is now estimated that inland coal requirements in 1954 will be 7,000,000 tons greater than in 1953.[4] It is conceivable that within the next decade the gap between supply and demand could increase to the order of 20,000,000 tons per annum. Electricity generated from nuclear energy may eventually come to the rescue, but there is no possibility that aid from this source can materialise for several years. Sir John Cockcroft has said[5] : "I envisage a development period of eight years, during which we shall have built and operated our Mark I power stations for five or six years and designed and built improved Mark II stations and possibly even a Mark III of a different type. We should then be in a position to build nuclear power units on a scale adequate to do the job of 20,000,000 tons of coal a year, and I think this could easily be achieved between 1965 and 1970—perhaps earlier if the need is great."

Filling the Gap

The gap that will exist between coal supplies and requirements for at least the next ten years has been plainly shown. How is it to be filled ? There are three possible ways :

(1) Increasing the production in the mining industry.

(2) Increasing the importation of fuel, principally petroleum.

(3) Increasing the efficiency of energy utilisation.

Increasing Production in the Mining Industry.—The prospects for greatly increased production from the mining industry are not encouraging.

In 1945 the Reid Committee made drastic recommendations for the mechanisation of the industry, which have formed the basis of the National Coal Board's programme of reconstruction. The recommendations included the maximum employment of coal-cutting and loading machinery, the replacement of rope haulage by locomotive and conveyor haulage, and the increased use of electricity underground. Heavy capital expenditure has already been incurred in putting these recommendations into effect. Fig. 3 illustrates the progress of mechanisation of the mines. For comparison, the effect of mechanisation in agriculture is shown graphically in Fig. 4. Since 1947 the percentage of coal mechanically cut has increased from 75 to 82 per cent ; the percentage mechanically conveyed from 75 to 88 per cent ; the percentage power loaded from 2·1 to 6·4 per cent. The horsepower of electric motors installed in mines has risen in the same time from 2·7 million to 3·4 million, and the number of locomotives underground from 185 to 468.

But in spite of these efforts to modernise and mechanise the mining industry an increase in production sufficient to solve our difficulties has not yet taken place. Fig. 3 shows the trends in coal production in terms of output per man-shift at the coal face since 1926 and in terms of output per worker in the industry since 1875. Neither graph indicates a spectacular or sustained increase in productivity as a result of mechanisation, though record figures for output per man-shift recently reported[4] give reason for qualified optimism.

It has also to be remembered that, partly for reasons outside the control of the National Coal Board and partly as a direct result of mechanisation, the quality of coal produced has declined and is likely to continue to do so. This applies to coking properties, size, ash content and sulphur content. The main reason for the deterioration is that, in the past, the best seams were preferentially mined and the coal has now to be obtained from thinner and dirtier seams.

It is therefore unrealistic to count on coal production increasing sufficiently to cover all our requirements.

Increasing Importation of Fuel, Principally Petroleum.—It is already realised that, short of finding natural gas, this is the easiest and only immediate solution to the fuel shortage. It was stated by the Minister of Fuel and Power in the House of Commons on July 9, 1954 : "Between the present time and the time when massive contributions are made by nuclear power there will be a period when it will be extremely valuable to this country to have some other supplement to our fuel and power resources. . . . There is only one source capable of making a sufficiently massive contribution and that is oil." It has since been announced[4] that, in addition to the new power station which is being built at Marchwood, which would have a coal consumption of 600,000 to 1,000,000 tons of coal per annum, seven other of its new power stations are to be provided by the British Electricity Authority with dual firing equipment capable of burning either coal or oil ; Marchwood will begin to burn oil in the autumn of next year.

The gas industry also is exploring methods of making gas without the use of coal. In addition

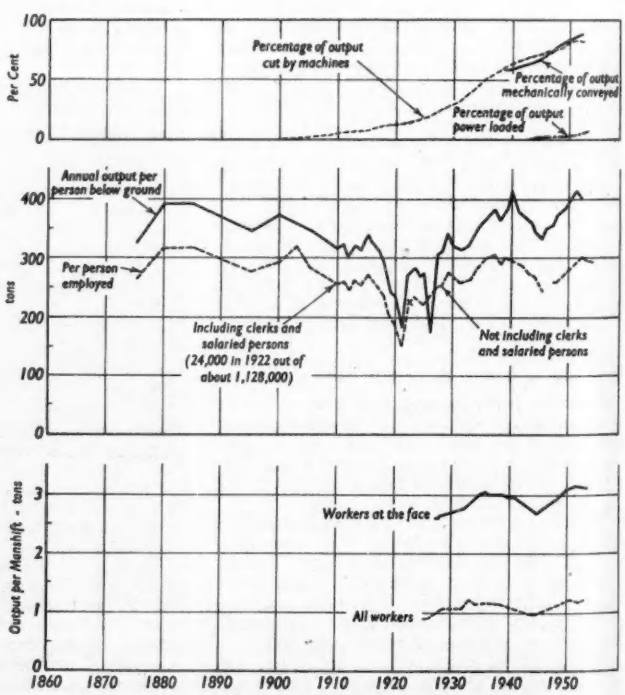


Fig. 3—Coal output in Great Britain—manpower and machines

to prospecting for natural gas, the industry has been developing processes for catalytic cracking of heavy fuel oil. Each Gas Board has decided to instal at least one of these plants, which will represent a saving of about 400,000 tons of coal a year. With regard to plant for the total gasification of coal, the chairman of the Gas Council[6] has indicated that, in view of existing uncertainty about the coal supply position, the industry attaches less importance to this development than to the pursuit of means for making gas which does not require coal.

The steel industry started conversion of certain of its plant to oil burning in 1946 and is already the U.K.'s largest single consumer of heavy fuel oil. Last year it used more than 1,000,000 tons.

Increasing the Efficiency of Fuel Utilisation.—From all points of view this is the most sensible method for filling the gap.

The problem of efficiency in the utilisation of energy is not a new one. In 1871 a Commission appointed "To inquire into the several matters relating to coal in the United Kingdom" presented its report. One of its sub-committees, the Committee on Waste in Combustion, had been required "to inquire whether there is reason to believe that coal is wasted by carelessness or neglect of proper appliances for its economical combustion." Many of the findings of this committee are worth quoting. Its general conclusion was that "without doubt coal is wasted by carelessness and neglect in large quantities . . . but, for some time past, in our manufactures, there have been constant and persevering efforts to economise coal by the application of improved appliances for its consumption." With regard to the real practical value of coal as a source of power in steam engines, the committee found that, on the average, "not more than one-thirtieth of the whole theoretical value of the coal is at present realised in power."

Other points made were :

Iron and steel manufacture : "It is certain that. . . there has been both an enormous waste of fuel in the production of heat and a considerable waste of the heat when produced." The committee drew attention to the possibilities of improved combustion "in a furnace designed for burning coal in a state of fine powder." This method was regarded as of possible application to the utilisation of small coal.

Production of steam power : After mentioning the enormous waste of fuel occasioned by the lack of insulation of boilers, especially in collieries and in ironworks, reference is also made to the subject of air pollution :

"Coal is piled upon the fire without any discretion, producing dense volumes of the blackest smoke, which is so much fuel actually thrown away; nor is the waste the worst part of it ; vegetation is destroyed or seriously injured for miles and that which acts so seriously on the plant cannot fail to be injurious to man. Dirt, disease and, indirectly, immorality, following like evil spirits in their dark train, are the natural consequences of that carelessness which marks the manufactures of the coal districts." The committee also studied many ways of promoting fuel efficiency by employing a better class of men as stokers, special education of stokers and utilisation of waste heat in general.

Domestic consumption of coal : "The prejudice in favour of the open fireplace is so strongly rooted that it will be long before the bulk of the population will be persuaded to adopt a more economical arrangement for warming their dwellings. . . . The defects of the open fireplace are recognised and modes of remedying them are within the reach of everybody ; yet certain it is that the public do not generally avail themselves of the opportunity of saving fuel by their adoption."

After expanding further on the luxury of the open fire "which is utterly wrong in principle," the report refers to the findings of an even earlier commission which reported in 1856 on the best methods of heating and ventilating dwelling-houses and barracks. "We have, however, the striking fact, showing the immovability of the public, that during the fifteen years which have elapsed since this commission began its labours and reported thereon, no economical result has been obtained."

Undoubtedly, in 1870 coal was consistently wasted in large quantities. But the "constant and persevering efforts to economise coal" had begun and that they have been effective is evidenced by the rapid rise in production of manufactured goods since then, which has been accomplished without a corresponding advance in the total consumption of coal by industry.

Several industries have undoubtedly made conspicuous progress in fuel efficiency in recent years, but it is nevertheless true that, in some branches of coal combustion or heat utilisation, little progress has been made since 1871, giving justification for Sir Ben Lockspeiser's comment, that we are the champion fuel wasters of Europe.

In the next section consideration will be given to the main wasters of fuel.

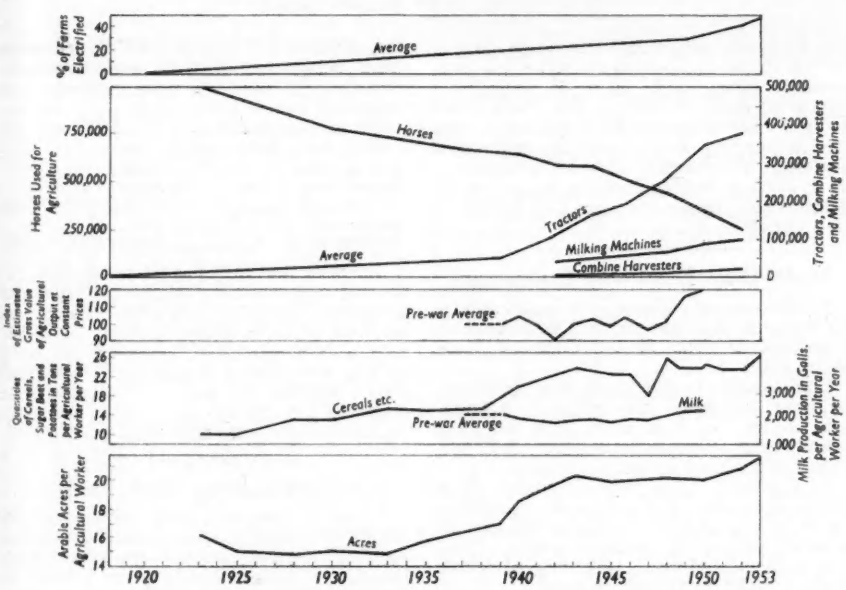


Fig. 4—Agricultural productivity in Great Britain—1923-1953

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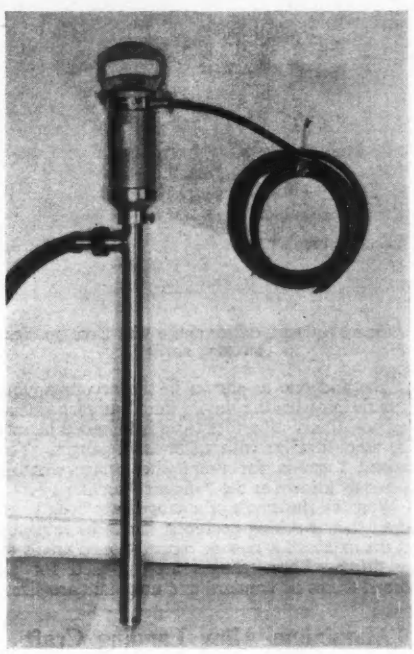
(To be concluded)

Portable Electric Pump

THE accompanying illustration shows the "Flux 300 Ex-N" portable electric pump, manufactured by Progress-Werke, Germany, which is being introduced into this country by the British Central Electrical Company, Ltd., 6 and 8, Rosebery Avenue, London, E.C.1. The pump is self priming, without check valves, and can easily be dismantled for cleaning. It is designed in such a way that no liquid remains inside after pumping has stopped. The lifting tube can be supplied either 2ft 3in or 3ft 7in long and has a diameter of 1·65in. The equipment weighs about 15 lb, and is powered by a ½ h.p., 220/240V universal motor, but other voltages can be catered for. The motor is operated by a switch in the handle and, being completely enclosed, it is stated to be explosion-proof and suitable for most inflammable liquids except carbon bisulphide. An output of 1600 to 2100 gallons per hour against a 12ft head is claimed for thin liquids, such as water. Viscous liquids, such as oils and lacquers, are more readily pumped by another version of this pump, which has a $2^{3}/_{32}$in diameter suction tube, and corrosive liquids are catered for by a version made largely from stainless steel.



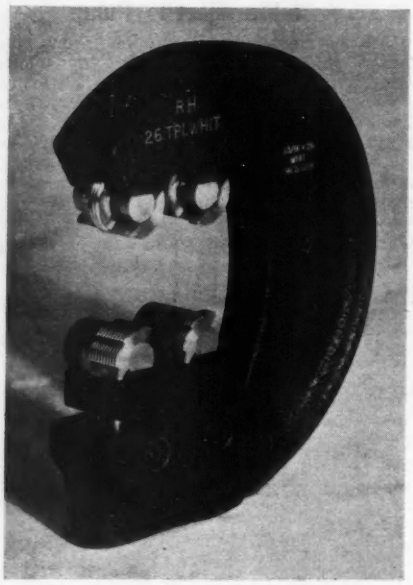
Self-priming portable electric pump which is explosion proof and can easily be dismantled for cleaning. Output 1600 to 2100 gallons per hour

Adjustable Thread Caliper Gauges

WE have received particulars of a new development of the "Newall-Tolimit" adjustable thread caliper gauge made by Tolimit Gauges, Ltd., 16, Peterborough Road, London, S.W.6. In these gauges a means of adjustment of 0·150in has been incorporated on one "go" and one "no go" anvil, whilst the opposing anvils are fixed. Each anvil has three positions to which it can be indexed as wear takes place, and the anvils are secured axially to reject components which have "drunken" threads. The gauges are supplied with the anvils set in their No. 1 position. When wear has taken place an index locating pin is withdrawn and each anvil rotated to the No. 2 position, where it is accurately located when the pin is replaced.

To assist in setting the gauging gap to fine tolerances a compound anvil adjustment is provided in which each turn of an adjusting screw advances or retracts the anvil by 0·012in.

The new gauges have non-rotating anvils and are made in two forms—one with radial



Adjustable thread caliper gauge with three position indexing anvils

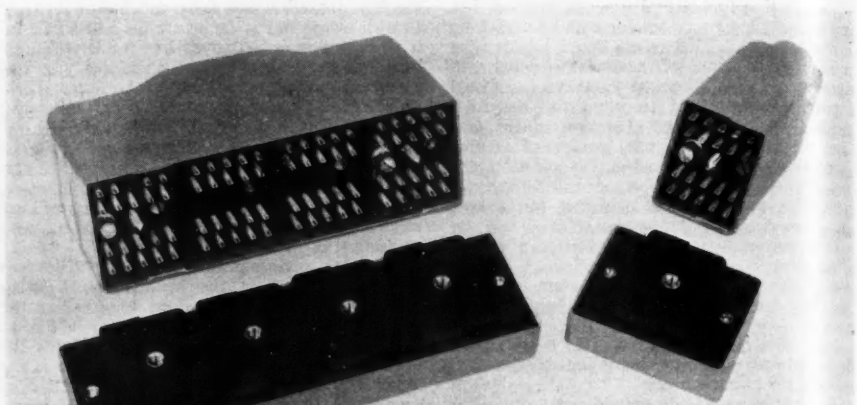
anvils, and one as shown in the accompanying illustration with the anvils fluted at each indexing position. The first form is intended mainly for users familiar with roller anvil gauges. The second form is for users who prefer what is generally known as the " chaser " anvil.

When all the anvils of a gauge have been worn at all their working positions it can be returned to the makers for new or reconditioned anvils to be fitted. These gauges are supplied for all thread forms in standard and non-standard sizes.

Aluminium Alloy Landing Craft

OUR photograph shows the all-aluminium alloy landing craft which was launched recently into the River Tees from slipways where large numbers of landing craft were constructed during the second world war. This vessel, which for commercial purposes is known as a ramped cargo lighter, was built by Head Wrightson Aluminium, Ltd., at Thornaby-on-Tees to the order and designs of the Fairmile Construction Company, Ltd., and has completed its trials satisfactorily. By using aluminium alloy for its construction the weight of the lighter, which has a length of 60ft and a beam of 16ft, has been kept to a minimum, the actual amount being 11 tons, or practically one-half that of the wartime steel version. Aluminium alloy to Specification N.5 has been used and it is expected that its high resistance to corrosion will help to keep maintenance costs to a minimum. All-riveted construction was adopted. The ramp in the bows is raised and lowered by means of a hand-operated winch. The lighter is destined for service at Brunei, North Borneo, where it will be lined with timber on arrival, and will be used for transporting stone from the new gravel deposits. Twin screws, each driven separately by a 75 b.h.p. Perkins diesel engine, propel the lighter, which is designed to carry a load of 30 tons on a draught of 4ft 2in.

A 60ft aluminium alloy ramped cargo lighter for service in North Borneo



80-way and 20-way plugs and sockets

Multi-Way Electrical Connectors

A NEW range of multi-way connectors suitable for electronic and light electrical work has been introduced by The Plessey Company, Ltd., Ilford, Essex.

These connectors give twenty-way, thirty-way, forty-way, sixty-way and eighty-way linkages, such as may be used in modern multi-unit assemblies in television transmitters, field telephones and railway signalling apparatus.

As can be seen from our illustration which depicts eighty-way and twenty-way assemblies, the plugs and sockets of these connectors are compact, each being contained within a rectangular aluminium case. Units may be packed closely together on a chassis or panel.

Various combinations of plug and socket systems can be built up : for example, two twenty-way plugs may be mated to one forty-way socket ; two thirty-way plugs may be mated to one sixty-way socket ; or four twenty-way or two forty-way plugs may be mated to one eighty-way socket.

In the interests of low contact resistance the plug and socket contacts are silver-plated and so made as to provide positive connection when fully engaged but to give a self-ejecting action when being disconnected. All contacts are shrouded by their respective housings as a protection against mishandling.

The main particulars of the multi-way connectors are tabulated herewith.

Flash test voltage	1500V d.c.
Working voltage	250V d.c. or 180V a.c.
Insulation resistance	100 megohms at 500V d.c.
Current carrying capacity	Up to 2A
Contact resistance	1 milliohm
Temperature range	−40 deg. Cent. to +70 deg. Cent.

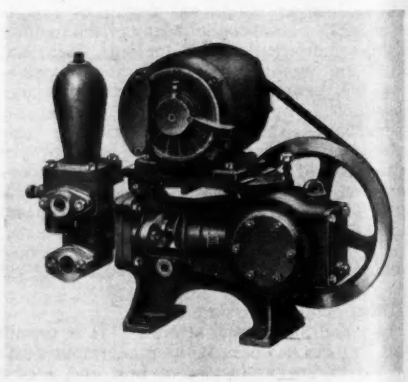
The cables are firmly clamped to the plug body, the soldered connections being relieved of mechanical load. The metal case of the plug may be removed, when necessary, without risk of disturbing the connections. To simplify the task of making the soldered connections in the small space available, the rear ends of contacts are staggered and specially machined to permit the ingress of solder in the hollow plug pins.

Single-Acting Ram Pump

A SINGLE-ACTING ram pump suitable for boiler feeding and other purposes requiring pressures up to 300 lb per square inch has been added to the range of small reciprocating pumps made by Lee Howl and Co., Ltd., of Tipton. These pumps are made in ten sizes with rams from ½in diameter by 1½in stroke to 1¾in diameter by 1¾in stroke, with capacities from 17 to 360 gallons per hour.

As can be seen from the photograph we reproduce below the pump can be arranged with the driving motor mounted on a plate on the crankcase. The crankcase is totally enclosed to form an oil bath and the cast iron pump barrel is fitted with a gunmetal sleeve. The valves are made of gunmetal and can easily be removed. A delivery air vessel is fitted.

If it is required to change the capacity of a pump the ram and its sleeve can be altered without need for modification to other parts of the pump.



Single-acting ram pump for boiler feeding or other purposes at pressures up to 300 lb per square inch

Continuously Acting Hydraulic Intensifier

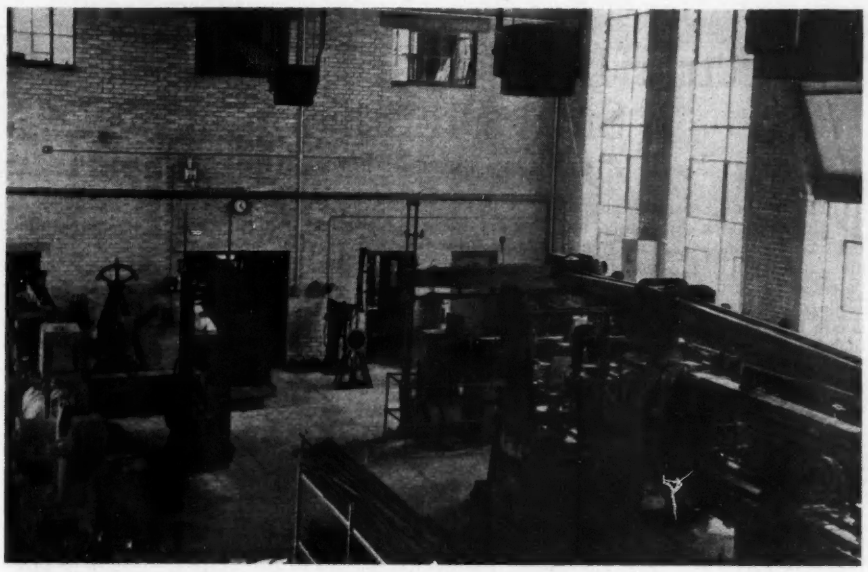
THE illustration below shows a continuously acting electrically controlled intensifier made by Fawcett, Preston and Co., Ltd., Bromborough, Cheshire. It is portable and self-contained and can be plugged into a 415V, three-phase supply at any convenient point. Driven by a 10 h.p. motor, the intensifier is stated to deliver pressure oil at up to 8250 lb per square inch, or pressure water at up to 6000 lb per square inch. As may be seen from the photograph, the unit is fitted with six castor wheels and consists of a tank surmounted by a cabinet which contains the intensifier, with the low-pressure pump and motor behind it. The control panel is on the left, and the delivery pipe and electric connections are on the right.

The low-pressure pump is capable of delivering up to 8 gallons per minute, the pressure being controlled at any desired value between 0 and 1500 lb per square inch by a pilot-operated unloading valve. The solenoid of the pilot valve is actuated by adjustable contacts on the low-pressure gauge. A relief valve and a non-return valve protect the pump from being overloaded.

The intensifier is of conventional design, with the low-pressure piston in the centre and a high-pressure piston at each end. Oil is supplied alternately to each of the low-pressure cylinder spaces by a solenoid-operated two-way valve controlled by limit switches. Each high-pressure cylinder has its own suction and delivery valve, and discharges into the common high-pressure main. The cylinders pump and charge in turn, thus giving a continuous pressure. Depending on whether water or oil is used as the high-pressure fluid, the intensification ratio is 4 : 1 or 5·5 : 1. A high-pressure gauge is provided with adjustable contacts, by means of which the required pressure is set. When it is reached the contacts interrupt the action of the two-way valve, which returns to the neutral position and stops the intensifier.

Start and stop buttons and indicator lights for the pump motor are fitted on the control panel. Other push buttons provide automatic and hand control of the intensifier, including inching.

The equipment can be employed either in its present form, or it can be split up and incorporated into an existing hydraulic system. If required, the intensifier may be mounted vertically.



Mechanical and structural engineering testing laboratory, showing 100-ton universal testing machine and other testing machines

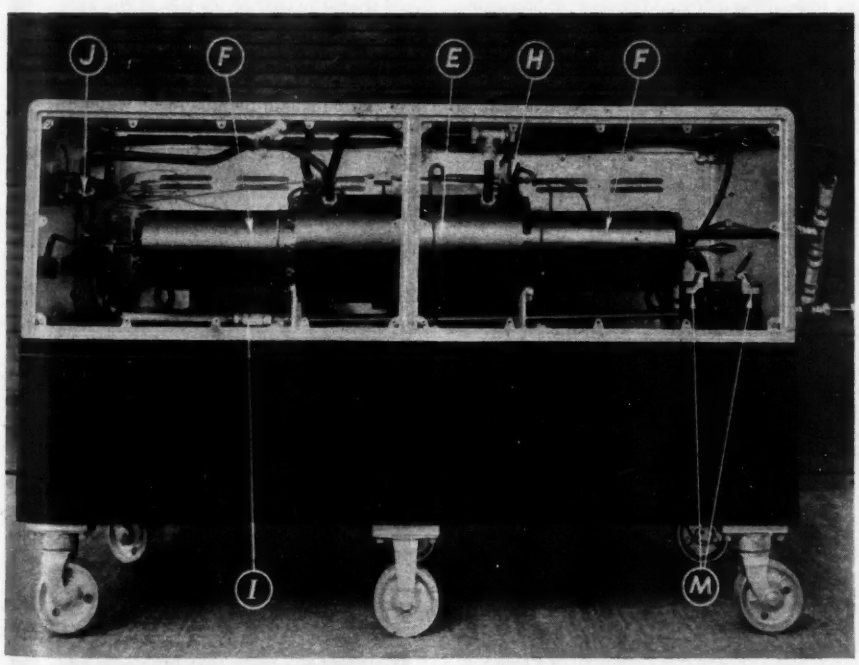
Materials Testing Laboratory

WE recently visited the new laboratories of R. H. Harry Stanger, at Summerfield House, Barnet Lane, Elstree, Herts, where all that firm's testing work is now carried out. The principal laboratory is for mechanical and structural testing and, with the workshop, covers an area of 3000 square feet. The new building also incorporates other testing laboratories which are at present in use for testing cement, concrete and building materials, textiles such as ropes and railway canvas, and some physical testing. There is 6000 square feet of laboratory space in the new building altogether.

The firm's work is organised into a section for engineering inspection and six testing sections, each with laboratory accommodation, covering physical testing (the physics section at present includes soil testing in its activities), chemical testing, metallurgical testing, the testing of cement, concrete and building products, textile testing, principally of the materials mentioned above, and mechanical and structural testing. The mechanical laboratory, which is shown in the accompanying illustration, is equipped with universal testing machines of 100 tons, 50 tons, 15 tons and 3000 lb capacity, and with various other testing machines such as an Izod machine, and Vickers and Rockwell hardness machines. There are also various testing rigs, which are assembled perhaps in conjunction with one of the universal machines, for specific tests as the occasion requires. The equipment has been chosen so that it may be readily adapted to any programme of testing which is called for. The larger structural tests are carried out in the open air and Bailey Bridge units are used to form test rigs of given sizes and strengths as they are required. An open-air testing site is also being constructed by laying down reinforced concrete beams 150ft in length, with load attachment points at 5ft centres ; these beams are able to take a load of 1 ton per foot run and they are to be spaced 5ft apart, to form a basic grid for structural testing. Two beams have been cast up to now, and others will be added as work progresses on the testing programmes.

The testing of concrete cubes is carried out at the laboratory on a large scale. A hydraulic machine with a capacity of 600,000 lb is used for this purpose. Extensive testing of cement is also carried out, and at various times tests to most of the European specifications are necessary. The physical properties of numerous building materials are also tested in this section. The work of the other sections follows along similar lines, and includes, for instance, a small laboratory for the rapid analysis of ferrous specimens for foundry work. Mobile laboratories are also equipped by the firm for special work, for instance, for the construction of an oil refinery, a concrete laboratory was set up in the mobile van, and sent to the site where, throughout the construction, it controlled the testing of incoming materials for concrete making, specified the concrete mixes at the concrete batching and mixing station, and tested the product.

The firm has a long record of experience in testing and inspecting engineering. W. H. Stanger, the father of the present senior partner, read a paper on the rotary kiln for Portland cement, before the Institution of Civil Engineers, in 1900, and was instrumental in introducing the rotary kiln into the cement industry. In the first years of the present century, a great deal of inspection work was carried out by the firm on the steelwork of a number of new buildings such as the Mall and Admiralty Arch, the new front of Buckingham Palace and the Victoria and Albert Museum. Other historic work with which it has been associated includes the contracts for the Nile dams and barrages, which were started in 1922 and did not finish until 1940.



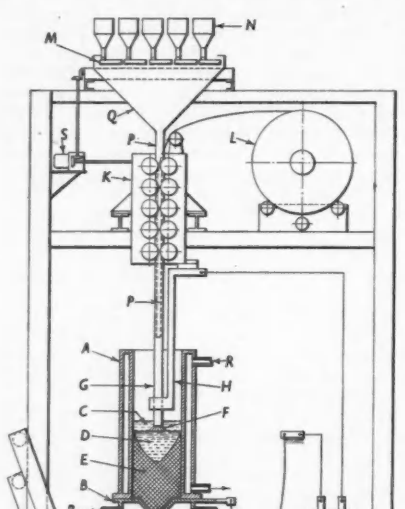
E—Low-pressure cylinder. *F*—High-pressure cylinders. *H*—Pilot valve.
I—Delivery valve. *J*—Suction valve. *M*—Limit switches.

Intensifier unit with side panels removed. Below the intensifier is the oil tank, behind it are the low-pressure pump and motor, and on the left is the control panel

Electric Ingot Process for Alloy Steel Production

BY OUR AMERICAN EDITOR

BECAUSE of the increasing demand in the United States for alloy steel ingots of uniform analysis which are free of segregation and facilitate a high yield of usable metal, the patented Electric Ingot Process of the M. W. Kellogg Company, of Jersey City, New Jersey, is now finding wide application in the production of both conventional alloy steels and jet engine "super-alloys." Much of the success of this melting process is due to the high tensile strength, high yield strength and good ductility which is required of materials going into such highly stressed jet engine components as the turbine wheel. Originally, alloy steels for such turbine wheels were being produced by conventional methods, leaving much to be desired. They contained the characteristic inconsistencies inherent in ingots melted and cast in the conventional way, such as non-metallic inclusions and voids. As the result of research work in the fields of melting and casting, it was realised that the electric ingot process, as it had become known, would produce a metal that had all the desirable properties required for turbine wheels. The process embodied such favourable characteristics as continuous melting and casting,



A—Water-cooled mould.
B—Water-cooled stool.
C—Molten flux.
D—Molten metal.
E—Solid metal ingot.
F—Current discharge.
G—Tubular electrode, consumable.
H—Contact shoe.
J—Power supply.
K—Tube forming machine.
L—Coil of strip.
M—Alloy metering devices.
N—Alloy hoppers.
P—Alloy conduit.
Q—Collecting hopper.
R—Water inlet.
S—Motor drive.

Diagram of electric ingot process melting machine

progressive solidification, uniform analysis, minimum segregation, flexibility, low cost of moulds per ton, and allowed small as well as relatively large ingots to be produced. The ingots were sound and pipeless and gave a high yield of usable metal.

One of the basic raw materials in this process is strip supplied in coils. For the iron-base alloys, this strip usually is plain low carbon rimmed steel. For non-ferrous alloys and alloys containing a very small percentage of iron, the strip is made of some appropriate material such as nickel. This strip usually is obtained in the cold rolled condition in a gauge and width suitable for forming into the desired size of electrode. As indicated in the accompanying diagram, the strip is passed through the tube-forming machine *K* where it is formed into a cylindrical electrode *G* with edges butted. After leaving the tube-forming machine, the tubular electrode is passed through contact shoe *H* where it picks up the current used for melting. After passing the contact shoe, it extends into the mould, where the current discharge *F* takes place below the slag blanket *C*. The location of the current discharge below the bottom of the contact shoe *H* is maintained at substantially a constant distance throughout the melting process. When one coil is nearly consumed it is welded to a new coil while melting is in progress.

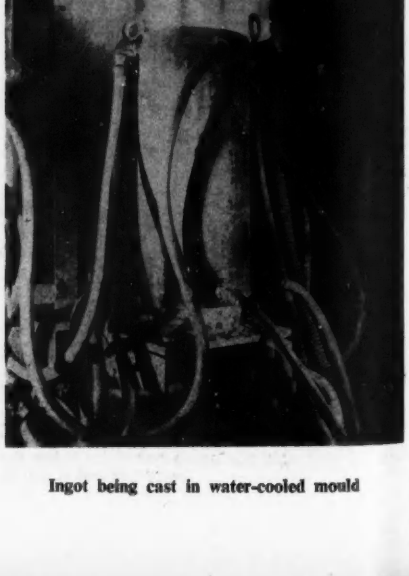
The melting process is initiated by supplying a small quantity of crushed alloying materials, mixed in the proportion of the alloy to be melted, to the centre of stool *B*. The mould and stool assembly is then raised until the end of electrode *G* touches the pile of alloying materials. A suitable supply of dry synthetic flux is added to the mould to cover the entire stool and material in it. Once the tube-forming machine is started, it is only a matter of seconds until the flux blanket is liquefied and the alloy-making process has begun. As the level of the alloy rises in the mould, the mould is retracted from the machine, and this motion continues until the desired length of ingot has been made. Since strip *L* is almost pure iron, it is necessary to add alloy materials to the melt to produce the grade of steel desired. The addition of these elements is accomplished by metering each one through a separate metering device *M*. The metering devices *M* are driven by the same motor that drives the tube-forming machine; in this way the rate of alloy addition is synchronised with the rate of electrode consumption. The alloying materials are obtained in a freely-flowing crushed condition and stored in hoppers *N*. These alloying materials are collected in hopper *Q* and conducted through the tube-forming machine and into the centre of electrode *G* through conduit *P*. These materials fall freely from the metering device to the current discharge in the mould but, since they are released only at the proportionate rate for the production of the alloy intended, there is no chance of a discrepancy occurring because of this free-falling action. The size of electrode *G* and the maximum rate at which the alloying materials are fed through it are controlled in such a way that it is impossible for the alloying materials to build up in the electrode if the end becomes plugged. This is accomplished by making certain that the internal volume of electrode *G* displaced per unit of time is greater than the total volume of all alloying materials added.

Not only does this process not require refractory linings, but, owing to the fast solidification resulting from the use of the water-cooled mould coupled with the relatively slow melting rate, progressive solidification is obtained. The metal freezes at the rate it is added. This does not mean that it freezes instantly, however, because there is a delay of a few minutes between the time of fusion of a part of the metal and the solidification of this same part. This time delay is a function of a depth of the bath *D*. Once this depth has been established in the early stages of the procedure, it does not change, regardless of the length of the ingot. There is a definite balance between the rate of heat input and heat removal, which has been found to be one of the most important aspects of the process. The superheated bath of molten metal *D*, which is contained in what might be considered a crucible of solidified metal of the same analysis, provides the most satisfactory mechanism imaginable for feeding the volume change that is constantly taking place as the metal solidifies. In addition to this feeding mechanism, the presence of this same molten bath has a distinct stress-relieving effect on the solidified metal, with the result that residual stresses in the ingots are considerably lower than those in ingots

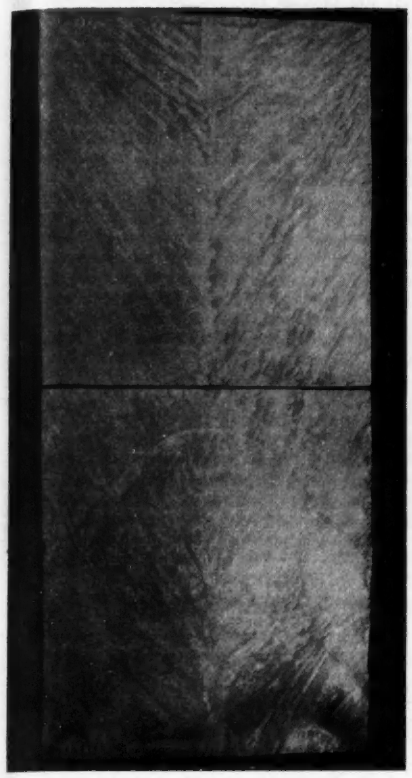
Automatic metering device controlling flow of granulated alloying materials

cast in the normal way. The combination of these two properties helps to produce ingots entirely free from either primary or secondary pipe, internal bursts or segregated materials, either metallic or non-metallic.

The raw materials used in the manufacture of these ingots are literally injected, in solid form, below the surface of a molten blanket of flux, where they are liquefied and put into thorough solution and then progressively solidified without ever having been exposed to the atmosphere. Because of this characteristic, the melting losses are very low, virtually all elements showing a yield of 100 per cent. The process is highly flexible in that the grade of steel melted can be changed at will simply by changing the adjustment of the metering device. There is no reason why the operator should not go directly from a heat of chromium-nickel steel to one of high-speed steel, because there are no refractories in the melting chamber to contaminate one heat with elements that may have been picked up from the previous heat. The process possesses much flexibility, as it is not only simple to change the size of the ingot being cast but as its length can be changed at will within a given standard-length mould. Since there is never more than a small amount of liquid metal in the mould at any one time, ingots of any desired length may be made without fear of



Ingot being cast in water-cooled mould



Macrosection in longitudinal plane of as-cast electric ingot of 16-25-6 alloy

producing unsound centres. It is thus possible to melt small heats of special alloys for test purposes under the same conditions that would be used for production purposes.

The machine which is now in operation at the company's Jersey City Works has four melting heads and eight moulds, permitting continuous casting. Trial ingots are produced from each new shipment of materials and are thoroughly analysed and inspected before the material is approved for production. Before the ingots are despatched, they are ground, cut, etched and given a final inspection. Since the as-cast surface of certain alloys is quite smooth, they are suitable for direct forging or roll reduction without any surface conditioning.

The company currently produces three principal "super-alloys": the Timken 16 per cent chromium, 25 per cent nickel, 6 per cent molybdenum alloy; the Westinghouse 13 per cent chromium, 26 per cent nickel, 3 per cent molybdenum, 1·8 per cent titanium alloy; and the Allegheny Ludlum 15 per cent chromium, 26 per cent nickel, 1·3 per cent molybdenum, 2 per cent titanium, 0·3 per cent vanadium alloy. The mechanical properties of the electric ingot process steels in both the cast and the worked forms have been found to be very good. The outstanding improvement as compared with conventionally-cast steels is in the ductility, and this is especially true in the central area of large sections, such as gas-turbine wheels. There are some undesirable aspects of this process, mostly connected with cost. No scrap can be used in the charge. In addition, some of the raw materials used cost more in the required granulated form than in the form used in conventional furnaces. These disadvantages eliminate the process from the field of carbon and low alloy steel production.

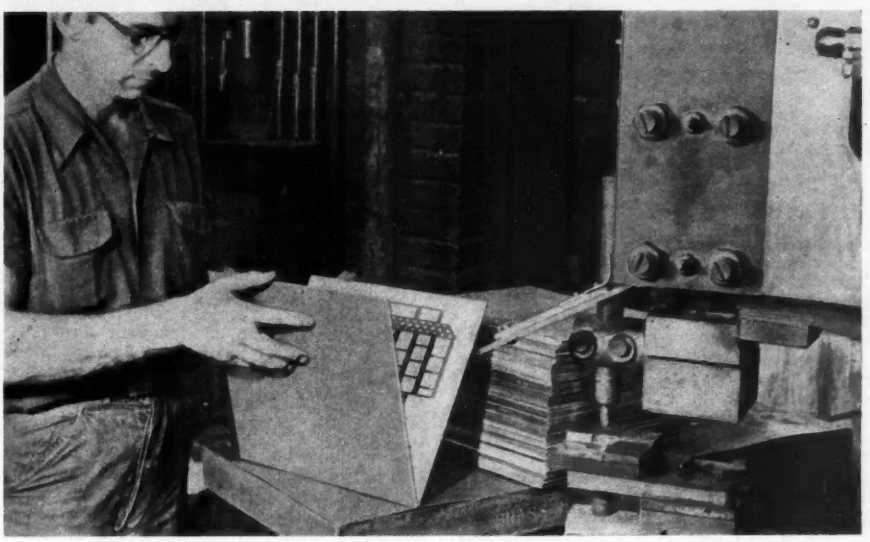
Large quantities of high-speed tool steels have been made by the process. Most of this steel was rolled directly from ingot to billet for subsequent reduction to bars. In no case was it necessary to hammer-cog before rolling. The outstanding difference between these and similar steels made by conventional practice is in their uniform carbide distribution with resulting uniform properties, their complete soundness and their freedom from internal bursts and hard spots.

Roll-Bonding Process for Evaporator Plates

THE Olin Mathieson Chemical Corporation, of East Alton, Illinois, has announced the development of an important roll-bonding process which is likely to change current design and production techniques in every industry dealing with temperature control. The new process makes it possible to create any pattern of tubing—however intricate—within a single homogeneous sheet of metal. The process, which may be considered to be a new application of the old art of roll-bonding, has already been proven commercially in the American refrigeration industry. In that particular case it has reduced re-tooling costs for evaporator plates for the latest "Frigidaire" model from 50,000 dollars to 50 dollars; has cut re-tooling time from a usual six months to one week; has lowered end product and production costs and, at the same time, has increased the efficiency of the plates by more than 25 per cent.

The four illustrations reproduced show the major stages in the production of refrigerator evaporator plates at the East Alton Works. Two flat pieces of aluminium or copper are cut to size and cleaned. With the aid of the silk screen printing process the pattern of the required tubing and other passages is applied to one of the flat sheets. The "paint" used to apply the pattern is a stop-weld material which prevents a surface painted with it from bonding to another piece of metal under heat and pressure. The stop-weld material is squeegeed on to the metal by means of a rubber roller. The two sheets are then placed face to face to form a metal "sandwich" and are spot-welded to keep them together in their proper relative positions. The "sandwich" is now heated by passage through a continuous furnace, preparing it for a complete bond between the two sheets. Subsequent cold rolling passes reduce the now homogeneous sheet of metal to the desired thickness. These rolling operations elongate the pattern several times. It is therefore necessary to plan the original silk screen pattern so that after elongation it will result in a perfectly proportioned final pattern.

After the completion of roll-bonding the fused sheet material is annealed. By now the entire



One silk-screened and one plain sheet of aluminium are assembled to form a "sandwich"

The spot-welded "sandwich" assemblies are prepared for hot rolling by passage through a continuous heating furnace

A roll-bonded "sandwich" sheet is inserted for inflation between the platens of a hydraulic press

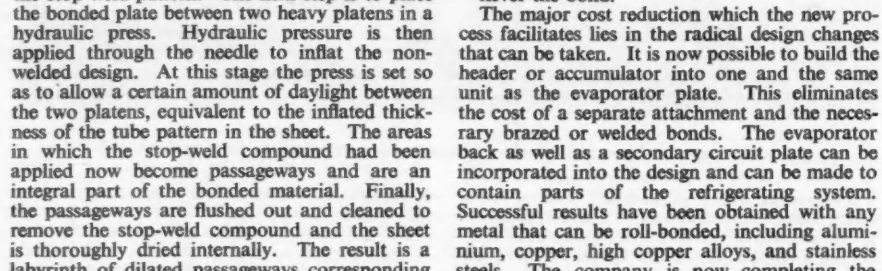
"sandwich" has become bonded, except for the area where the stop-weld pattern had been applied. Following the annealing process, one end of the now elongated metal plate is trimmed. This step bares the lead-in end of the stop-weld pattern. A needle, much like that used to inflate a football, is then inserted into the bared end of the stop-weld pattern. The next step is to place the bonded plate between two heavy platens in a hydraulic press. Hydraulic pressure is then applied through the needle to inflat the non-welded design. At this stage the press is set so as to allow a certain amount of daylight between the two platens, equivalent to the inflated thickness of the tube pattern in the sheet. The areas in which the stop-weld compound had been applied now become passageways and are an integral part of the bonded material. Finally, the passageways are flushed out and cleaned to remove the stop-weld compound and the sheet is thoroughly dried internally. The result is a labyrinth of dilated passageways corresponding exactly to the tube pattern required in the evaporator plate.

Since the sheet and the tube pattern are homogeneous, they provide maximum heat conductivity. Previous methods of braze-welding or soldering pipes to an evaporator plate used to create air spaces between the tubes and the plate. This condition greatly reduced the thermal conductivity, since heat cannot be transferred any more efficiently than the ability of the intermediate welding material to transfer heat. Tests have shown that the bond strength of the "sandwich" is equivalent to the strength of the individual sheets. There is absolute fusion of the metal with complete grain growth across the interface. Tensile tests under extreme conditions have proven that when pressures are increased to the breaking point it is the tube which ruptures —never the bond.

The major cost reduction which the new process facilitates lies in the radical design changes that can be taken. It is now possible to build the header or accumulator into one and the same unit as the evaporator plate. This eliminates the cost of a separate attachment and the necesrary brazed or welded bonds. The evaporator back as well as a secondary circuit plate can be incorporated into the design and can be made to contain parts of the refrigerating system. Successful results have been obtained with any metal that can be roll-bonded, including aluminium, copper, high copper alloys, and stainless steels. The company is now completing the construction at East Alton, Illinois, of a large works intended to put the new process on a mass production basis.

Early tests have indicated that any pattern which can be drawn on a piece of paper can be reproduced as tubing within a metal sheet, and that as many as six sheets of metal can be bonded at one and the same time. Even complicated parallel or multiple tubes, running at right angles to each other in two or more layers, can be made effectively. It has been mentioned that the process may be used to produce the honeycomb structures which are beginning to find application in aircraft design. The passageways in a sheet of roll-bonded aluminium would impart structural strength in the same way as corrugation adds so much strength to cardboard. Thus aircraft could be designed with roll-bonded structural members carrying coolant at the same time, in order to solve the problems of heat at supersonic speeds.

The new method, according to the Massachusetts Institute of Technology, brings solar heating of houses closer to reality. It is believed that a roof made of roll-bonded sheets is the most efficient means yet found for trapping the heat of the sun. Water within the tubing is heated by the rays of the sun, and hot water is then drawn through the house within the passageways of roll-bonded walls, ceilings and floors. To date, however, it is in the refrigeration industry that the process has really been tested and proved. During the past eighteen months the company has been producing roll-bonded evaporator plates for the Frigidaire Division of General Motors. They have been made in a small pilot plant at the East Alton Works, and more than 250,000 are already in use in homes throughout the United States.



The inflation needle is removed from the completed evaporator plate after the tube pattern has been formed

Award of Turbine Contract to English Firm

THE recent award to the English Electric Export and Trading Company of a contract to supply two Francis turbines rated 68,000 h.p. at 128·6 r.p.m. for the Table Rock dam of the U.S. Army Corps of Engineers has been interpreted as a welcome change in the purchasing policy of the present American administration. It may be recalled that on several occasions in the past, the so-called "Buy American" clause has led to the rejection of British and European low bids on turbine and generating plant. In the present case, the British low bid of 1,066,662 dollars was only 11·8 per cent under the American second bid of 1,191,715 dollars by the Newport News Shipbuilding and Drydock Company. Since the "Buy American" Act was enacted in 1933, the narrowest margin that had previously won an award for a foreign low bidder was 18 per cent. The "Buy American" legislation allows a government agency to add 25 per cent to a foreign low bid for purposes of comparison with the bid of an American firm. The general practice has been to apply the full 25 per cent differential in the evaluation of tenders. The Table Rock dam is on the White River in Missouri near the Arkansas state boundary line, upstream from the reservoir impounded by the Bull Shoals dam. The bids for the two Table Rock turbines had to be adjusted for the credits that the various bidders were willing to allow the U.S. Government to cover the expense of model tests. The English Electric Company included no credit for this work in its bid; the Newport News Company, however, offered a deduction of 18,410 dollars on a total bid of 1,210,125 dollars, reducing the net cost to the Federal Government to 1,191,715 dollars.

The five bids for the Table Rock turbines were opened on September 29th at the Little Rock district office of the U.S. Army Corps of Engineers. Four American firms as well as the one British firm submitted prices. Following the second low bid by Newport News, the other gross bids, with deductions for model tests, were: Allis-Chalmers Manufacturing Company, 1,238,540 dollars, less 23,000 dollars credit; S. Morgan Smith Company, 1,316,205 dollars, less 25,000 dollars credit, and Baldwin-Lima-Hamilton Corporation, 1,350,000 dollars, less 17,000 dollars credit. Several American bidders have submitted formal protests to the award in letters and telegrams to the Defence Department, pointing out that the contract was given to a foreign manufacturer although the differential between the foreign bid and the low domestic bid was less than one-half of the 25 per cent traditionally required under the "Buy American" Act. In calculating the savings supposedly accruing from the award, the American manufacturers pointed out that no consideration was given to the taxes which would have been paid if the contract had been awarded to a domestic manufacturer.

Industrial and Labour Notes

Engineering and Shipbuilding Wages

Last week, the Confederation of Shipbuilding and Engineering Unions submitted to the Engineering and Allied Employers' National Federation and to the Shipbuilding Employers' Federation new claims for wage increases for engineering and shipbuilding workers. These claims asked for increases of 15s. a week for skilled men and 10s. a week for unskilled men. The present minimum rates are £7 4s. 10d. for a forty-four-hour week for skilled men and £6 4s. 10d. for unskilled men.

In putting forward this latest claim it is understood that the unions are urging, on behalf of workers in the engineering industry, that there should be three or four intermediate grades which would give higher pay to men who were formerly unskilled, but who have become production workers as mechanisation has developed. There is also a request for a modification of the holiday pay agreement in the engineering and shipbuilding industries. Two weeks' paid holiday are granted, and the unions are asking that in future holiday pay should be based on average earnings instead of on hourly rates.

Railway Wages

It was announced on Monday that the Minister of Transport had made a fuller reply to the National Union of Railwaymen on the subject of railwaymen's wages. It will be recalled that, on December 13th, the Minister met representatives of the N.U.R., who had already put forward a suggestion that the Government should restore to the railways some part of the £124 million profit accruing from railway operation during the years 1940 to 1946. This suggestion was made by the union in view of the British Transport's contention that the state of its finances made it impossible to consider further wage increases.

At that interview, the Minister of Transport told the union representatives that he could not contemplate anything in the nature of a subsidy to help new railway wage claims to be met, and he also explained that the £124 million represented little more than a book-keeping transaction. At the same time, he promised to consult further with his colleagues in the Government about the points raised. The reply which the Minister has now made to the union said that as the normal processes of negotiation and arbitration had not been exhausted, the Government could not intervene in the matter of railway wages without dealing a serious blow to the negotiating machinery in the railway industry and in the rest of industry as well. The reply pointed out that the Government could not properly substitute itself for the British Transport Commission as a party to wage negotiations, but it was strongly of the opinion that the National Union of Railwaymen should take part in further discussions with the British Transport Commission to see whether agreement could not be reached. In the event of agreement not being reached, the Minister added, the right course for the N.U.R. was to take its claim to the Railway Staff National Tribunal. The situation was considered on Tuesday, in the light of the Minister's communication, by the executive of the National Union of Railwaymen. A statement issued by the N.U.R. afterwards said that it was clear that " all forms of negotiation on the wages question " had been exhausted. The statement went on to say that the union was determined to win the balance of the 15 per cent on all railway wages on pre-December, 1953, rates. The executive had therefore decided to withdraw the labour of all N.U.R. members in the railway industry as from midnight on January 9th next. This decision, of course, would involve N.U.R. members employed on British Railways, London Transport, railway workshops, docks and elsewhere.

Meanwhile it has been announced that the trade union side of the Railway Shopmen's National Council has decided to submit to the British Transport Commission an application for wage increases for men employed in British Railways workshops. The amounts mentioned are 15s. a week for the skilled grades, 12s. 6d. a week for semi-skilled and 10s. for unskilled men. The claim is thus in line with those put forward for engineering and shipbuilding workers, as stated in the preceding note.

Railway Freight Charges Scheme

The British Transport Commission says that, as required by the Transport Act, 1953, it has completed a draft of the Railway Freight Maximum Charges Scheme, and is now engaged in consultations with important bodies of transport users upon the substance of the draft. When these are completed the final draft scheme is to be submitted to the Transport Tribunal for a full inquiry, at which all bodies representing railway users and other interested parties are entitled to be heard.

The Commission has explained that any charges scheme subimtted to the Tribunal must confine itself solely to establishing maximum charges. The new scheme, therefore, will not settle the actual charges which will normally be paid as these will be a matter for competitive quotation beneath the maxima and for commercial negotiation between the parties concerned. Failing agreement as to any particular traffic and provided that other means of transport cannot be used, the consignor may appeal to the Tribunal to fix an actual rate. All that the maximum charges scheme can do, therefore, is to provide a broad framework within which the railways will be free to exercise commercial enterprise and play their full part in the national economy. The British Transport Commission says that " it will be no part of the scheme to bring about a general increase in the freight revenues of the Commission."

Overseas Trade

The final figures of the United Kingdom's overseas trade in November, which have been issued this week by the Board of Trade, show that the value of recorded exports was only £196,500,000, while the value of imports rose to £338,800,000. The value of re-exports was £5,500,000.

These figures, of course, reflect the unsettled conditions following the dock strike in October. They show, too, that during November there was a greater clearance of the imports held up by the strike than exports. The Board of Trade says that this was to be expected since most of the ships entering strike-bound ports had to be unloaded prior to taking up export cargoes. It seems fairly clear, the Board adds, that the value of imports recorded in December will be less inflated than in November, whilst exports may be expected to show an increase compared with preceding months. Meanwhile, it should be noted that, even with abnormally low figures for October and November, the total value of the United Kingdom's exports in the first eleven months of this year, at £2418 million, was £61,000,000, or 2½ per cent, higher than the figure for the comparable period of 1953, and more than in the first eleven months of 1951, when the previous highest figures were recorded. One comment made by the Board of Trade about imports is that during October and November there were substantial arrivals of coal, averaging in value nearly £3,000,000 a month.

About import and export prices, the Board of Trade says that in November there was a rise of one point in the index of import prices (1953=100), bringing it back to 100, and an unchanged export price index of 99. This resulted in the terms of trade index showing an adverse movement of one point to 101. During the first eleven months of this year, import prices, on average, have been about 2 per cent below those of the corresponding period of last year, but the slight downward tendency throughout last year and until March of this year has since been reversed and the index in November was at the same level as in the middle of 1953. The export price index has shown no significant trend since the decline, which set in after the peak of March and April, 1952, came to an end during the second quarter of last year. A fairly steady fall, however, in the price index for exports of metals over the past two years has been largely responsible for depressing the index for manufactured goods below the 1953 level.

Exports of Office Machinery

The Office Appliance and Business Equipment Trades Association has reported further increases during this year of office machinery exports. In the first ten months of this year, exports of British typewriters were valued at £2,540,686, which was slightly in excess of the figure recorded for the whole of 1953, and nearly £500,000 above the value of the total production in 1948. Another section which showed improvement in the first ten months of this year was duplicating machinery and parts, the exports of complete machines being valued at £1,126,032, compared with £819,308 in the corresponding period of last year.

Altogether, office machinery and equipment exports from the United Kingdom from January to October reached a value of £10,029,545, which was nearly £1,000,000 above the value achieved in the comparable period of 1953. It is stated that Australia was the largest individual customer, the value of office machinery exported there being £1,800,000.

Industry in Northern Ireland

The Northern Ireland Ministry of Commerce has issued a report on the working of the Re-equipment of Industry Acts during the year ended May 17, 1954. The purpose of these Acts, it should be explained, was to assist industrial undertakings in Northern Ireland to increase their productive capacity. The amount of grant payable does not exceed one-third of the expenditure incurred in a scheme, and there is provision for grants towards expenditure involved in work carried out under approved schemes in the period May 18, 1950, to May 17, 1957, but there was also a provision in the Acts that the schemes must be submitted to the Ministry of Commerce by January 1, 1954.

By the closing date, 408 applications had been received, covering a total estimated expenditure of £21,878,000, of which £17,375,000 was required for plant and machinery and £4,503,000 on buildings. The applications included eighty-one under the heading " engineering, manufacture of chemicals and miscellaneous," involving an estimated expenditure of £3,212,000. The report now issued says that by May 17th last, 161 applications had been approved involving expenditure estimated at £11,220,000. Of that number, there were twenty-five schemes in the engineering, chemical manufacture and miscellaneous category, representing an expenditure of £1,453,000.

Engineering Equipment Users Association

In 1949, the Engineering Equipment Users Association was formed, its general object being to provide its members with facilities for exchanging information on the standardisation of engineering materials and equipment which they use in common, and thus for presenting their co-ordinated views as users. The Association says that since its inception, there has been considerable progress in the fields of mechanical, electrical and civil engineering along the lines originally intended by the founder members and close co-operation with the British Standards Institution has been maintained. It has been decided recently to extend the scope of Association by making provision for associate membership. Acceptance for either full or associate membership of the Association is at the discretion of the council, the primary qualification of candidates being that they must be predominantly users rather than manufacturers of engineering equipment. The headquarters of the Association are at 20, Grosvenor Gardens, London, S.W.1.

Notes and Memoranda

Rail and Road

LIGHTWEIGHT DIESEL TRAINS ON BRITISH RAILWAYS.—It is announced by British Railways North Eastern Region that the first 3½ months' operation of lightweight diesel trains in the West Riding has shown very satisfactory results. The introduction of more frequent services with speedy diesel trains has resulted in an additional 80,000 passengers being carried between Leeds and Bradford, with an increase in takings of £4558. Between Leeds and Harrogate there were increases of over 28,000 passengers and £3474 in revenue. The through traffic between Bradford, Harrogate and Knaresborough increased by 14,743 in numbers of passengers and £2506 in receipts.

EARTH SLIP ON THE UXBRIDGE LINE.—During the week-end December 4th/5th, London Transport carried out a large-scale operation near Uxbridge Station on the Metropolitan and Piccadilly Lines to arrest the movement of a large earth slip. Some 400 yards east of the station the cutting is about 45ft deep and a massive surcharged concrete retaining wall up to 30ft high runs on a slight curve on the south side. Slight signs of earth movement had been under observation when suddenly, during the week-end of November 20th/21st, a cavity appeared in the public footpath near the top of the wall and exposed the foundations at the corner of an adjacent house ; at the same time, deep vertical cracks opened on the surface of the ground indicating a deep and extensive slip. Observations indicated a slide on a cylindrical surface, including the whole of the retaining wall and the track formation for a length of some 200ft. Immediate measures were taken to reduce the weight at the back of the wall by dragline excavation, the presence of adjacent property and of electric cables and telephone services in the footpath somewhat restricting the extent of the work. Despite the earth movement, the wall was found to be remaining nearly upright. Concrete struts beneath the tracks bearing against the toe of the wall were inserted commencing on November 26th, their far ends being secured against concrete blocks and an existing retaining wall. Trenches for these struts were dug under the tracks during traffic, as well as during non-traffic hours at night. Ready-mixed concrete was delivered by road and tipped by chute from the road bridge high above the line into railway wagons for transport and placing. A tranverse joint of building board was inserted in each strut to allow some further movement of the retaining wall to take place without load on the struts, while the concrete was hardening. Though the movement of the wall had been checked, it was considered advisable to proceed with the scheme for stone pitching with a 4ft raising of the tracks to load the toe of the slip. Granite pitching and limestone ballast were already on rail from Leicestershire and Somerset. The large raising on stone pitching required the permanent way to be removed. Normal traffic was therefore suspended, giving a total engineering possession of fifty-seven hours. When the two passenger tracks were raised by 4ft for a length of 60 yards with a run-out of this lift at the ends over a combined length of 340 yards, and the third track was lifted to suit the new level of the adjacent passenger roads. The tracks were removed one at a time by crane and 1800 tons of granite and 2000 tons of limestone ballast were unloaded by hand, some 400 permanent way men being employed. Limitations of time and space prevented the employment of mechanical unloading plant. During the week-end, a converted six-car passenger train was stabled in an adjacent siding to provide temporary accommodation for the staff employed and as a control office. The organisation of this track lift at short notice called for a special planning effort, London Transport states, complicated by the flooding of some quarries from which stone was ordered and the congestion of loaded wagons in some areas due to the effect of gale conditions on the ports. This track raising would have buried a line of thirty-two h.t. and signal cables attached to the lower part of the wall. The lifting of these into a temporary wooden troughing together with incidental work to signals and track circuits, was in itself a work of some magnitude. The whole operation was completed within the scheduled time.

Air and Water

" CUTTY SARK."—The famous clipper " Cutty Sark " made her last voyage when she sailed recently from the East India Dock to Greenwich and entered the dry dock, which has been specially built to receive the ship, through a channel cut for that particular purpose from the dock to the river. The dock, constructed of mass concrete, is 265ft in length by 60ft wide, this width being adopted so that most of the ship's hull can be seen from ground level.

MARINE PHOTOGRAPHIC EXHIBITION.—Two identical exhibitions, consisting of photographs portraying British exploits at sea in the fields of discovery, trade and combat, famous ships, examples of sea literature and navigation, have been prepared by the British Council for showing overseas. One exhibition, now in Gibraltar, has been shown in Malta and will be on view later in Portugal, while the other exhibition is to tour Chile, Peru and the West Indies.

LAUNCH OF " IVERNIA."—On Tuesday, December 14th, the second of the three liners designed for the Canadian service of the Cunard Steamship Company, Ltd., was launched from the yard of John Brown and Co. (Clydebank), Ltd. The ship, named " Ivernia," has the same dimensions as the " Saxonia," which sailed on her maiden voyage in September last, namely, length between perpendiculars, 570ft; breadth moulded, 80ft ; depth moulded to " A " deck, 46ft 3in. She will carry 110 first-class passengers and 830 tourist class passengers.

CUMBERLAND BUILDING EXHIBITION.—The Parliamentary Secretary, Ministry of Works, Mr. J. R. Bevins, will open the first building exhibition of the new year, at Workington, Cumberland, on Monday, January 3rd, at 2.30 p.m. The exhibition is to be held at the College of Further Education, Park Lane, Workington; it is sponsored by the College and the Cumberland Building Trades Employers Association, and supported by the West Cumberland Building Trades Association and the Ministry of Works, and will remain open until Saturday, January 8th.

LLOYD'S WRECK RETURNS.—We have received from Lloyd's Register of Shipping a copy of the returns of merchant ships totally lost, broken up, &c., during the quarter ended June 30, 1954. The world total of steamships and motorships lost consequent upon casualty amounted to 33 ships of 40,100 tons, none of which belonged to Great Britain and Northern Ireland, though eight of 1932 tons were registered in the other Commonwealth countries. The corresponding totals for ships lost not consequent upon casualty were 112 ships of 331,348 tons, 40 ships of 76,331 tons, and 7 ships of 22,425 tons respectively.

SCHOOL OF AERONAUTICS.—Short Bros. and Harland, of Belfast has made an offer of financial assistance to enable Queen's University, Belfast, to establish a school of aeronautics. The company has offered £7000 towards the capital cost of equipping the proposed school and £4000 a year towards the annual cost until such times as the University Grants Committee recommends that it should be borne by the recurrent parliamentary grant. The school will be situated in one of the wings of the Engineering and Science Building now being erected. Its laboratory facilities will be made available not only to University students, but also to students of the Belfast College of Technology. The Vice Chancellor has stated that the endowment is sufficient to create a Chair of Aeronautics.

INSULATION MATERIAL BROCHURE.—Marinite, Ltd., has published a brochure dealing with the use of " Marinite " for marine applications, such as divisional bulkheads, linings, ceilings, structural insulation to give built-in fire protection. The brochure gives a note upon the range of materials, discusses finishes and decoration and includes standard dimensions, together with recommended specifications and weights of materials for various applications. There are short notes upon working, finishing and handling, and also illustrations showing the methods of erection of panels for different styles of bulkheads, &c. Information is included concerning structural insulation, sound insulation and fire-resisting divisions, together with a list of fire test reports. Tables give British and metric sizes and weights of " Marinite " panels and list the physical properties of the material.

Miscellanea

SUSSEX INDUSTRIES EXHIBITION AND TRADE FAIR.—The Federation of Sussex Industries, Ltd., announces that it has booked the Corn Exchange, Brighton, from September 7 to 17, 1955, for its ninth exhibition.

FOUNDATIONS FOR HIGH BUILDINGS.—Last week, an abstract from Professor Skempton's paper with the above title, presented at the Institution of Civil Engineers' symposium on high buildings on December 7th, was printed in THE ENGINEER. Fig. 5 of our abstract was entitled " La Latino Americana Building, Mexico City," and Fig. 6 " High Paddington." These captions were, in fact, transposed, and Fig. 5 showed the High Paddington project.

ELECTRONIC VALVES AND CATHODE-RAY TUBES.—The Board of Trade has referred a new subject, namely, the supply of electronic valves and cathode-ray tubes, to the Monopolies and Restrictive Practices Commission, which is to report both about the facts of the matter and their bearing on the public interest. Any person or organisation wishing to offer evidence should write to the Secretary of the Monopolies and Restrictive Practices Commission, 3, Cornwall Terrace, Regent's Park, London, N.W.1.

SWEDEN'S IRON AND STEEL INDUSTRY.—The Association of Swedish Steelworks has stated that, in the first nine months of this year, exports of iron ore from Sweden totalled 10,350,000 tons and were thus nearly 1,000,000 tons lower than in the corresponding period of last year. Exports of pig iron, at 36,100 tons, were about 500 tons less, but exports of sponge iron, at 12,900 tons, were 3000 tons higher in the first nine months of this year than in the comparable period of 1953. The Association says that in the first three quarters of this year Sweden's production of pig iron was 674,300 tons, of sponge iron 38,100 tons, and of steel ingots 1,330,400 tons.

Contracts

THE BRITISH TRANSPORT COMMISSION has placed a contract with the Tees Side Bridge and Engineering Works, Ltd., Middlesbrough, for 300 42-ton bogie bolster wagons.

THE BUTTERLEY COMPANY, Ltd., has received a contract from Stewarts and Lloyds, Ltd., for a large tonnage oxygen plant to be installed at Corby iron and steel works. The plant will be to the design of Air Products Incorporated, of Allentown, Pennsylvania, U.S.A., from whom the Butterley Company, Ltd., hold the manufacturing rights for Great Britain, certain European countries and the British Commonwealth. It will be capable of producing 200 tons of 99·5 per cent purity oxygen per day. The value of the contract is put at over £300,000.

Personal and Business

MR. J. J. DAVIES has been appointed publicity manager of Holophane Ltd., Elverton Street, London, S.W.1.

GENERAL SIR G. IVOR THOMAS, G.C.B., has joined the board of Rubber Improvement, Ltd., Wellingborough, Northants.

MR. W. H. KUSHNICK has been appointed executive director of the Instrument Society of America, Pittsburgh, U.S.A.

MR. C. J. PRATT has been appointed work study and productivity officer of the Association of British Chemical Manufacturers.

MR. M. M. HALLETT has been appointed managing director of Chamberlin and Hill, Ltd., Chuckery Foundry, Walsall.

C. RYAN AND CO., 2–20, Pancras Street, London, W.C.1, states that from January 1st its title will be Charles Ryan and Co., Ltd.

R. J. RICHARDSON AND SONS, Ltd., Commercial Street, Birmingham, 1, has acquired the share capital of Rowland Priest, Ltd., Cradley Heath, Staffs.

MR. H. W. SIMPSON has been appointed secretary, and Mr. J. C. N. Baillie, chief commercial officer, of the North of Scotland Hydro-Electric Board.

MR. K. S. PEACOCK, chairman and managing director of Guest, Keen and Nettlefolds, Ltd., has been appointed a director of The United Steel Companies, Ltd.

MR. ERIC H. UNDERWOOD has been appointed director of public relations to the United Kingdom Atomic Energy Authority. Mr. Stanley White has been appointed press officer to the Authority.

BABCOCK AND WILCOX, Ltd., states that Mr. A. S. Peacock has been appointed manager for Latin America, with general responsibility for the company's business there, including factory development in Brazil.

VICKERS-ARMSTRONGS Ltd. announces the formation of the following subsidiary companies :—Vickers-Armstrongs (Aircraft), Ltd., Vickers-Armstrongs (Engineers), Ltd., and Vickers-Armstrongs (Shipbuilders), Ltd.

MR. J. S. DUNCAN, chairman and president of Massey-Harris-Ferguson, Ltd., and Mr. Cecil N. McKay, chairman and managing director of H. V. McKay Massey Harris Pty., Ltd., state that negotiations are proceeding for the closer amalgamation of their two companies.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., states that Mr. D. N. de Mattos has been appointed sub-district manager at the office at 119, Victoria Street, Bristol. Mr. B. Barton and Mr. E. R. Seadon have been transferred to the company's engineering staff at Crown House, Aldwych, London, W.C.2.

ASSOCIATED BRITISH ENGINEERING, Ltd., has acquired the whole of the issued share capital of British Polar Engines, Ltd. In addition to British Polar Engines, Ltd., the Associated British Engineering group comprises The Bergius Company, Ltd., Henry Meadows, Ltd., A. C. Morrison (Engineers), Ltd., and H. Widdop and Co., Ltd.

THE BRITISH TRANSPORT COMMISSION, in pursuance of the policy of decentralisation, announces the following appointments on British Railways :—Mr. H. C. Johnson, chief operating superintendent, Eastern Region ; Mr. A. P. Hunter, chief operating superintendent, and Mr. L. Sproat, assistant operating superintendent, North Eastern Region.

RALEIGH INDUSTRIES, Ltd., announces the retirement of Sir Harold Bowden from the chairmanship of the company on January 1st. Sir Harold, who joined the company in 1899 and who has been chairman since 1921, will remain a director and will take office as president. He is to be succeeded as chairman by Mr. G. H. B. Wilson, the present deputy chairman and managing director.

REGENT OIL COMPANY, Ltd., 117, Park Street, London, W.1, states that Mr. G. E. G. Hope-Johnstone is resigning from the board at the end of the year to take up his appointment as vice-president of Trinidad Leaseholds (Canada), Ltd. Mr. J. A. J. Nicholas succeeds Mr. Hope-Johnstone as sales director of Regent Oil Company, Ltd., Mr. O. H. Fish has been appointed dealer sales manager, and Mr. G. W. Limmer, commercial sales manager. Mr. H. J. Tanner becomes London branch manager and Mr. C. D. B. Freeland, Western branch manager.

LONDON TRANSPORT announces the following appointments in the office of the assistant electrical engineer-(generation) :—Mr. J. Collins, generating station superintendent (Lots Road) ; Mr. W. Ward, generating station superintendent (Greenwich) ; and Mr. G. F. Withers, generating station superintendent (Neasden). London Transport also announces the appointment of Mr. G. Fernyhough as operating manager (country buses and coaches) in succession to Mr. B. H. Harbour, who has recently become a member of the London Transport Executive.

VICKERS LTD. announces the retirement of Sir James Reid Young from executive duties and from the boards of subsidiary companies. He will continue as a director of the parent company and of Metropolitan-Cammell Carriage and Wagon Company, Ltd. Viscount Knollys has been appointed deputy chairman of Vickers Ltd., and Major-General C. A. L. Dunphie becomes chairman of Vickers-Armstrongs Ltd., retaining his present office as managing director. Mr. E. J. Waddington has been appointed to the board of Vickers Ltd. as director of administration and is succeeded as secretary by Mr. E. P. Tomlinson. Vice-Admiral Sir Charles Simeon is retiring from the board of Vickers Ltd. These retirements and appointments all take effect on January 1st.

British Patent Specifications

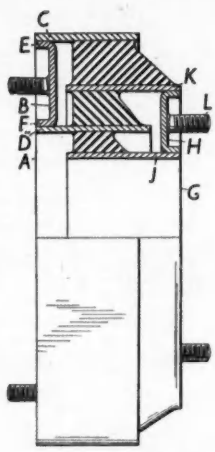
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

POWER TRANSMISSION

718,599. May 16, 1951.—FLEXIBLE COUPLINGS, Dunlop Rubber Company, Ltd., 1, Albany Street, London, N.W.1. (*Inventor: Paul Brierley.*)

The coupling comprises a driving member *A* consisting of a driving plate *B* and two tubular hexagonal members *C* and *D*. The driving plate has a periphery in the form of a hexagon and a hexagonal concentric hole, the edges of the hole being parallel with corresponding sides of the periphery. The driving plate is formed as a channel with a metal flange *E* on the outer periphery and another *F* on the inner periphery of the hole. The two tubular members *C* and *D* are of the same length but of different sizes across flats. The larger member *C* is a press fit on the outer periphery of the driving plate and the hole in the plate is a press fit on the outer periphery of the smaller member *D*. A driven member *G* comprising a driven plate *H* and two tubular members *J* and *K* is built up in exactly the same way as the driving member. The inner tubular member *D* of the driving member extends almost to the base portion of the driven plate *H* and the edge of the outer tubular member *K* of the driven member remote from the driven plate is similarly spaced from the driving plate *B*. A hexagonal rubber element is moulded in each of the channels and is bonded to adjacent faces. Screwed studs *L* are projection-welded to the base portions of the driving and driven plates for securing the coupling between flanges on shafts to be coupled. Portions of the rubber elements are subject to compression when the coupling is torsionally strained.—*November* 17, 1954.

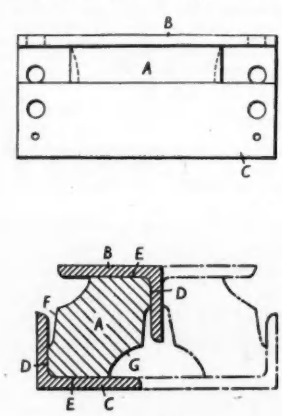


No. 718,599

BEARINGS AND SUPPORTS

718,605. October 3, 1951—RESILIENT MOUNTINGS FOR MACHINERY, The National Research Development Corporation, 1, Tilney Street, London, W.1. (*Inventors: Philip Edwin Spencer and James William La French Norman.*)

Referring to the drawing, a resilient element *A* of material such as a natural rubber, is bonded between two steel angle-bars *B* and *C*. The cross-sectional shape of the resilient element, as shown, is an irregular polygon of eight sides, the resilient element having four pairs of opposite and similar sides, *D*, *E*, *F* and *G*. Two of the opposite pairs of adjacent sides *D* and *E* are shaped to fit the re-entrant surfaces of the angle-bars *B* and *C* and are bonded to it. The angle-bars are arranged in parallel planes and are off-set relatively to each other as shown. The other two opposite pairs of adjacent sides *F* and *G* are free and lie within the space defined by the re-entrant surfaces of the angle bars *B* and *C*, which extend laterally beyond the resilient element *A*. The free sides *G* in this example are concave and the sides *F* are partly plane, and partly concave. The angle-bars project longitudinally beyond the element *A* to provide space for bolt holes, as shown, for bolting the mounting to a machine base and to the main supporting structure. These mounting or seating members may be manufactured in a range of lengths utilising the same cross-section, for a range of static loads. The members are suitable for mounting moderately large and moderate speed internal combustion engines.—*November* 17, 1954.

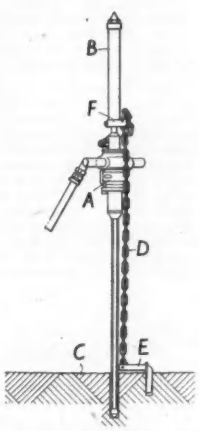


No. 718,605

MINING AND CIVIL ENGINEERING

718,756. October 21, 1952.—METHOD OF DRILLING ROCK AND HARD MATERIALS, Tampereen Pellava- ja Rauta-Teollisuus Osake-Yhtio, Tampere, Finland. (*Inventor: Niilo Asikainen.*)

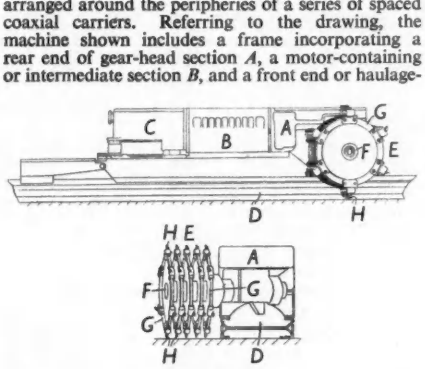
The object of the invention is to provide a method and improved means for readily and quickly supporting a drill, to largely eliminate the manual effort involved. In the arrangement shown the drilling machine *A* carries at its upper end the feed cylinder *B*. The feed cylinder is connected to the rock *C* to be drilled, by the chain *D*. The lower end of the chain is anchored by the angle anchor *E*. The upper end of the chain is fixed fixed to the feed cylinder by placing a link into a fork *F* on the feed cylinder. When a distance corresponding to the length of the cylinder is drilled, the operation is discontinued while compressed air escapes from the cylinder. When the cylinder has returned to its initial position the chain attachment is reset.—*November* 17, 1954.



No. 718,756

719,169. August 18, 1952.—MINING MACHINES, Anderson, Boyes and Co., Ltd., Flemington, Electrical Works, Motherwell, Lanarkshire, Scotland. (*Inventor: Alexander Anderson.*)

The invention relates to improvements in mining machines of the type including a rotary cutting implement extending on one side of the machine frame and incorporating cutter elements or picks arranged around the peripheries of a series of spaced coaxial carriers. Referring to the drawing, the machine shown includes a frame incorporating a rear end of gear-head section *A*, a motor-containing or intermediate section *B*, and a front end or haulage-gear section *C*. *D* denotes an armoured conveyor upon which the machine is adapted to be traversed. Supported from the gear-head *A* is a rotary cylindrical cutting implement *E* secured on a horizontally and laterally extending driving arbor or shaft *F* having its axis displaced to the direction of travel of the machine by, for example, 15 deg. or up to 20 deg. The cutting implement includes several discs *G* spaced on the shaft, each with one or more cutter picks *H* which, due to the disposition of the shaft, rotate in planes which are oblique to the direction of travel of the machine. Provision may be made for adjustment of the shaft angle. As a result of the slewing of the axis of the cutting implement to the direction of travel of the machine, ridges of mineral which would ordinarily be left below and/or above the cutting implement are removed by the oblique milling action of the series of picks *H*. Thus, after each traverse of the machine, the mine floor in the path of the machine is left free from uncut ridges.—*November* 24, 1954.

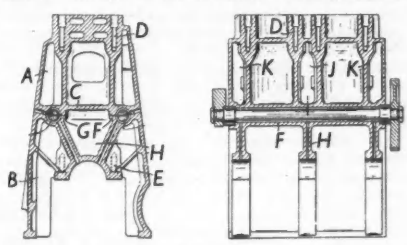


No. 719,169

INTERNAL COMBUSTION ENGINES

718,777. January 2, 1953.—COMBINED CYLINDER AND CRANKCASE UNITS, Gustav Ospelt, Vaduz, Liechtenstein.

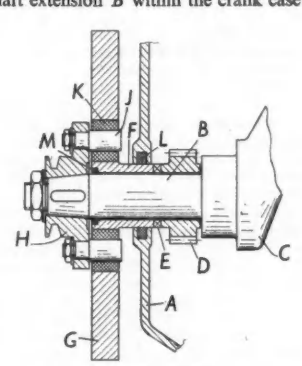
The invention enables the arrangement of the cylinder head screws and ties to be independent of the arrangement of the crankshaft bearings and adaptable to the housing design. The engine housing shown in the drawing is a casting comprising the cylinder block *A* and the crankcase *B*, which are separated by a horizontal wall *C*. The tapped holes *D* provide for the attachment of the cylinder head. The combustion forces occurring in the cylinders create a two-directional thrust acting through the crank assembly on the crankshaft bearings and the bearing retaining screws screwed into the tapped holes *E*, and on the cylinder head and the cylinder head retaining screws screwed into the tapped holes *D*. For this reason, ties, as shown, are provided between the tapped holes of the cylinder head retaining screws and the tapped holes of the bearing screws. Stiffening members formed as beams *F* and *G* extend in the axial direction of the crankshaft and have connected to them the ties and the bearing supports which form part of the bearing walls *H*, the ties and the bearing walls being positioned in staggered relation in different transverse vertical planes. Scavenging ducts *J* and *K* between the cylinders are also provided. As shown in the drawing, the beam-like stiffening-members consist of ribs or thickenings of the wall *C*, which separate the crankcase from the cylinder block. These members are hollow and serve to accommodate balancing shafts *J*, each of which have at one end a gear with a balancing mass, and at the other end a weight mounted diametrically opposite on the shaft to balance mass. The cavities accommodating the balancing shafts are connected by lubricating ducts with the crankshaft bearings. The external casing of the engine is provided with connecting surfaces for auxiliary components or accessories, such as a Roots blower, lubricant for which is supplied through lubricating ducts which extend from the cavities, the connecting flanges of the accessories having lubricating bores.—*November* 17, 1954.



No. 718,777

719,095. February 8, 1952.—POWER TRANSMISSION, Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

The invention relates to power transmission means for the driving of subsidiary parts in internal combustion engines comprising a resilient connection between the crankshaft and the element transmitting the drive. In the drawing *A* is an end wall of the crank case and *B* is an extension of the crankshaft *C*. The element *D* for transmitting the drive to the tappet shaft may be a spur sprocket, helical or worm wheel. The wheel *D* is freely mounted upon the crankshaft extension *B* within the crank case and is coupled in the rotation direction by means of dogs *E* to the part *F* which is constructed as a flywheel disc *G* or is fixed or elastically connected to appropriate flywheel masses mounted freely on the extension *B*



No. 719,095

of the crankshaft. It may be made in one with the part *F* instead of being separate and coupled as shown. For the driving of the part *F* from the crankshaft, it is coupled in the rotational direction to a hub part *H*, mounted on the end of the extension *B*, the coupling being effected by means of the pins *J* engaging in rubber sleeves *K* inserted in holes in the disc *G*. A seal *L* serves for sealing the wall *A* against the outside of the part *F*, whilst a seal indicated at *M* serves for sealing the part *F* against the crankshaft extension *B*. The hub part *H* is constructed as a V-belt pulley.—*November* 24, 1954.

Technical Reports

Road Research Technical Paper No. 33 : *Further Studies in the Compaction of Soil and the Performance of Compaction Plant.* H.M. Stationery Office. Price 3s.—This report gives the results of tests by the Road Research Laboratory on the performance of compacting machines used in this country, much of it dealing with work carried out since the publication of paper No. 17.

The soils chosen for the investigations were representative of most British soils, namely, a heavy clay, a silty clay, a sandy clay, and sand and a gravel-sand-clay (hoggin). Fourteen kinds of compaction plant were studied. They included track-laying tractors, which are not strictly compaction plant, because they tow such plant and therefore contribute to the compaction process. The machines used in the tests were smooth-wheeled rollers, a pneumatic-tyred roller, sheepsfoot rollers, rammers, vibrating smooth-wheeled rollers and plate vibrators.

An 8-ton smooth-wheeled roller produced very high states of compaction with all the test soils. A 12-ton pneumatic-tyred roller was equally satisfactory in compacting the cohesive soils, but its performance was poorer on the granular soils. Although their outputs were much lower, a 12 cwt frog-rammer and four makes of 2 cwt power rammers were also capable of producing high states of compaction with all the soils. Vibrating rollers and vibrating plate compactors achieved the best results on the granular soils. These machines were not found to be particularly satisfactory for the compaction of the cohesive soils. The report gives the outputs of the machines and also the costs per cubic yard of satisfactorily compacting soil.

The selection of the moisture content at which to compact is a difficult problem, the report states. It suggests that soils should be compacted at their natural moisture content measured below the top 3ft to 4ft of soil usually affected by weather conditions.

The compaction necessary in road embankments depends on the amount of settlement which can be tolerated and on the requirements for the stability of the slopes. The state of compaction of a number of existing embankments has been measured. The results showed that the main bulk of the fill need not usually be compacted to a higher state of compaction than that corresponding to 10 per cent of air voids. A higher state of compaction is probably needed in the top 1ft to 2ft of fill to prevent settlement due to the action of traffic and vibration over a long period.

Specifications for the state of compaction required in earthworks are usually expressed in terms of the maximum dry density obtained in the laboratory compaction tests. The report considers this method unsatisfactory and suggests an alternative method of specification in terms of a maximum percentage of air voids in the soil.

Fumigation with Methyl Bromide under Gas-Proof Sheets.—Pest Infestation Research Bulletin No. 1. H.M.S.O. for D.S.I.R. Price 2s. 6d. (65 cents U.S.A.), by post 2s. 7½d.—It is not always possible to fumigate foodstuffs and other stored products in the most efficient way, i.e. in specially designed gas-tight chambers, or sealed warehouses. An alternative way of doing the job is the fumigating of stacks of stored goods under gas-proof sheets, and the most effective fumigant to use with this technique has proved to be methyl bromide. Early experience of the method was confined to the fumigation of small stacks which could be covered by a single sheet, but it is now possible to treat large stacks of up to 3000 tons in buildings or in the open air by using a number of overlapping sheets. Methods have been developed for distributing the methyl bromide satisfactorily and it has been found that losses by leakage can be kept to a minimum if the stack is properly prepared. The Bulletin describes the physical and chemical properties of methyl bromide, the preparation of the stacks for fumigation and the training of operators. Sections deal with the handling of the fumigant, including transfer from large to small containers, the procedures and equipment for applying the fumigant and methods of airing the stack after fumigation. Detailed specimen instructions to operators-in-charge are given, together with methods of determining the effectiveness of a fumigation.

Launches and Trial Trips

PRESIDENT BRAND, oil tanker ; built by the Furness Shipbuilding Company, Ltd., for the Northern Steamships, Ltd., South Africa ; length overall 591ft 11in, length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, summer draught 32ft 3½in, deadweight 24,600 tons ; twenty-seven cargo oil tanks, two cargo oil pump rooms, four 500-tons per hour cargo oil pumps, two 150-tons per hour stripping pumps ; trial speed 14 knots ; two 75kW steam-driven generators, one 35kW diesel-driven generator, two Scotch boilers ; N.E.M.-Doxford single-acting, two-stroke oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m. Trial, November 23rd.

SIR WILLIAM HARDY, research trawler ; built by Hall Russell and Co., Ltd., for the Department of Scientific and Industrial Research ; length between perpendiculars 131ft, breadth moulded 27ft 6in, depth moulded 15ft, specially insulated fish rooms, quick freezing plant, laboratory ; Metropolitan-Vickers diesel-electric main machinery, propulsion motor 600 s.h.p. at 200 r.p.m., power supplied by six diesel-driven generating sets. Launch, November 29th.

ORMESBY QUEEN, trawler ; built by John Lewis and Sons, Ltd., for Talisman Trawlers, Ltd.; length overall 113ft 6in, length between perpendiculars 100ft, breadth moulded 20ft, depth moulded 10ft 9in ; one 15kW diesel-driven generator, one 10kW belt-driven generator ; Crossley Mark H.R.N.6 diesel engine, 440 b.h.p. at 300 r.p.m. Trial, December 2nd.

BRITISH PATROL, oil tanker; built at the Neptune Yard of Swan, Hunter and Wigham Richardson, Ltd., for the British Tanker Company, Ltd.; length between perpendiculars 515ft, breadth moulded 69ft 6in, depth moulded 37ft 6in, deadweight 16,000 tons on 30ft summer draught ; eleven passengers ; twenty-seven cargo oil tanks, two cargo oil pump rooms, four 500 tons per hour cargo oil pumps, steam deck machinery ; two 150kW diesel-driven generators, one 75kW steam-driven generator ; trial speed 15 knots ; Swan Hunter-Doxford oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6400 b.h.p. at 115 r.p.m., Doxford-Bibby detuner, two Scotch boilers. Trial, December 2nd.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Jan. 6th.—MERSEYSIDE SECTION : College of Technology, Byrom Street, Liverpool, 3, " Some Interesting Applications of Electronics to Photography," D. M. Neale, 7 p.m.——N.W. SECTION : Reynolds Hall, College of Technology, Sackville Street, Manchester, " Problems in the Design and Production of Car Radio," discussion opened by C. L. Caiger, 7 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Jan. 11th.—Church Institute, Hull, Presidential Address, " Some Uses of Solvents," J. B. Moller, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Thurs., Dec. 30th.—BIRMINGHAM CENTRE : College of Technology, Suffolk Street, Birmingham, Display of New Lighting Fittings, 6 p.m.

Wed., Jan. 5th.—EDINBURGH CENTRE : Manor Club, 12, Rothesay Place, Edinburgh, 3, " Street Lighting Lantern Design," T. M. Christie, 7 p.m.——NEWCASTLE CENTRE : Liberal Club, Pilgrim Street, Newcastle, Presidential Address, E. C. Lennox, 6.15 p.m.——SWANSEA GROUP : S. Wales Electricity Board's Demonstration Theatre, The Kingsway, Swansea, Informal Meeting, Three Papers followed by a Discussion, 6.30 p.m.

Thurs., Jan. 6th.—CARDIFF CENTRE: S. Wales Electricity Board's Demonstration Theatre, The Hayes, Cardiff, " Studies in Interior Lighting," J. M. Waldram, 5.45 p.m.——GLASGOW CENTRE : Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, " High Bay Lighting," F. Jones, 7.30 p.m.——NOTTINGHAM CENTRE : E. Midlands Electricity Board, Smithy Row, Nottingham, " Recent Studies in Glare," R. G. Hopkinson and P. Petheridge, 6 p.m.

Fri., Jan. 7th.—BATH AND BRISTOL CENTRE : Royal Hotel, Bristol, " Studies in Interior Lighting," J. M. Waldram, 6.15 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Jan. 4th.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, " The Writing and Presentation of a Technical Report for a Non-Technical Board of Directors," W. J. Dickie, 7 p.m.

Wed., Jan. 5th.—SOUTHAMPTON BRANCH : Polygon Hotel, Southampton, " Industrial Instrumentation," C. M. V. Benwell, 7.30 p.m.

Thurs., Jan. 6th.—PETERBOROUGH BRANCH : Campbell Hotel, Bridge Street, Peterborough, Ten-minute Papers by Members, 7.30 p.m.

Fri., Jan. 7th.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, " Gas Turbines in Industry," J. R. Needham, 7.30 p.m.

INSTITUTE OF METALS

Tues., Jan. 4th.—OXFORD LOCAL SECTION : Cadena Cafe, Cornmarket Street, Oxford, " Titanium," P. Litherland Teed, 7 p.m.

Thurs., Jan. 6th.—BIRMINGHAM LOCAL SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, a debate on the motion, " This house considers that, at the present stage of industrial metallurgy, empirical methods of research are more profitable than those employing the fundamental approach," proposed and seconded by D. V. Atterton and J. Crowther, opposed and seconded by A. R. E. Singer and G. Parkin, 6.30 p.m.——LONDON LOCAL SECTION : 4, Grosvenor Gardens, London, S.W.1, " Some Aspects of Twinning and Kinking in Metals," A. H. Cottrell, 6.30 p.m.

INSTITUTE OF REFRIGERATION

Tues., Jan. 4th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, " Ground and Airborne Equipment for Cooling Aircraft Cabins," N. Anderson, 5.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Jan. 11th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, " The Design and Application of Tractor-Mounted Loaders," J. C. Bamford, 2.15 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Wed. and Thurs., Dec. 28th, 29th and 30th.—CHRISTMAS LECTURES FOR BOYS : Great George Street, Westminster, London, S.W.1. Tuesday : " Speed and the Motorway," E. W. W. Richards, 3 p.m.; Wednesday : " The Wonders of Big Bridges," H. Shirley Smith, 3 p.m.; Thursday : " The Story of Communications in Tropical Africa," R. W. Taylor, 3 p.m.

Tues., Jan. 4th.—WORKS MEETING : Great George Street, Westminster, London, S.W.1, " The Reconstruction of Deptford Creek Bridge," F. M. Fuller and J. N. C. Couper, 5.30 p.m.——N.W. ASSOCIATION : Reynolds Hall, College of Technology, Manchester, " Some Applications of Reinforced Concrete in the Gas Industry," T. Andrews, 6.45 p.m.

Wed., Jan. 5th.—N.W. ASSOCIATION : 9, The Temple, 24, Dale Street, Liverpool, " Some Applications of Reinforced Concrete in the Gas Industry," T. Andrews, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Jan. 3rd.—S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, Discussion on " Sandwich Courses," opened by W. H. Taylor, 6 p.m.

Tues., Jan. 4th.—S. MIDLAND CENTRE : Town Hall, Birmingham, Faraday Lecture, " Courier to Carrier in Communications," T. B. Terroni, 6 p.m.——N. MIDLAND CENTRE : British Electricity Authority, 1, Whitehall Road, Leeds, 1, " The Co-ordination of Insulation of High-Voltage Electrical Installations," J. S. Cliff, 6.30 p.m.——MEASUREMENTS AND RADIO SECTION : Savoy Place, London, W.C.2, " Equipment of Instrumental Accuracy for Recording and Reproduction of Electrical Signals Using Cinematographic Film," H. McGregor Ross, 5.30 p.m.

Wed., Jan. 5th.—SUPPLY SECTION : Savoy Place, London, W.C.2, " The Economic Selection of Cooling Towers for Generating Stations," G. F. Kennedy and P. H. Margen, " The Application of Friction-Heat Transfer Correlations to Cooling Tower Design," P. H. Margen, 5.30 p.m.

Thurs., Jan. 6th.—ORDINARY MEETING : Savoy Place, London, W.C.2, " Problems of Hydro-Electric Design in Mixed Thermal-Hydro-Electric Systems," T. G. N. Haldane and P. L. Blackstone, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Wed., Dec. 29th.—APPLIED MECHANICS' GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion, " Gaps in the Knowledge of Applied Mechanics," 6.45 p.m.

Fri., Dec. 31st.—GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : " Development of the Lost-Wax Process of Precision Casting, 1949–1953," J. S. Turnbull, 5.30 p.m.

Tues., Jan. 4th.—BIRMINGHAM A.D. CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, " Vehicle and Road Illumination," J. H. Nelson, 6.45 p.m.

Wed., Jan. 5th.—HYDRAULICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion, " Hydraulic Transmission : The Relative Advantages of Oil and Water," 6.45 p.m.

Fri., Jan. 7th.—GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, " Impact Torsion Experiments," and " Experiments on the Effect of Rate of Testing on the Criterion of Failure of Certain Mild Steels," N. G. Calvert, 5.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., Jan. 5th.—NORWICH SECTION : Assembly House, Theatre Street, Norwich, " Fuel Efficiency in the Factory," E. J. Tickner, 7.30 p.m.——NOTTINGHAM SECTION : Victoria Station Hotel, Nottingham, " The Human Aspect in Production Planning and Control," B. G. L. Jackman, 7 p.m.——WOLVERHAMPTON SECTION : Anchor Hotel, Wednesbury, " Lock Design and Manufacture," C. G. Smith, 7.15 p.m.

Thurs., Jan. 6th.—READING SECTION : Great Western Hotel, Reading, " Work Measurement," T. U. Matthew, 7.30 p.m.——S. WALES AND MONMOUTHSHIRE SECTION : S. Wales Institute of Engineers, Park Place, Cardiff, " Standardisation in the Process Industries," E. W. Greensmith, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Jan. 4th.—MIDLAND COUNTIES BRANCH : Midland Institute, Birmingham, " Load Factor Methods of Design of Reinforced Concrete," F. G. Thomas, 6 p.m.——N. IRELAND BRANCH : College of Technology, Belfast, " Reinforced Concrete Portal Frames in Northern Ireland," J. D. Boyd, 6.45 p.m.

Fri., Jan. 7th.—LANCASHIRE AND CHESHIRE BRANCH : College of Technology, Manchester, " The Present Situation on Retaining Wall Design," P. W. Rowe, 6.30 p.m.——WESTERN COUNTIES BRANCH : University of Bristol Geology Lecture Theatre, Bristol, " Recent Bridge Works in Bristol District," H. G. Lakeman, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Fri., Dec. 31st.—POPULAR FILM EVENING : Pepys House, 14, Rochester Row, London, S.W.1, " Sweet Thames Run Softly," " West Country Journey," " Spinning Wheels," 7 p.m.

Wed., Jan. 5th.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, " Power Press Safety," J. H. Price, 7 p.m.

Fri., Jan. 7th.—Pepys House, 14, Rochester Row, London, S.W.1, Film Evening, 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Jan. 7th.—Engineers' Club, Albert Square, Manchester, " Engineering Practice in the Gas Industry," T. Andrews, 6.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Jan. 4th.—N.W. BRANCH : College of Technology, Sackville Street, Manchester, " Some Applications of Reinforced Concrete in the Gas Industry," T. Andrews, 6.45 p.m.——MIDLAND COUNTIES BRANCH : Birmingham and Midland Institute, Paradise Street, Birmingham, " Load Factor Methods of Designing Reinforced Concrete," F. G. Thomas, 6 p.m.

Wed., Jan. 5th.—N.W. BRANCH : Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, " Some Applications of Reinforced Concrete in the Gas Industry," T. Andrews, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Jan. 4th.—SECTION LECTURE : 4, Hamilton Place, London W.1, " Recent Advances in the Knowledge of Transonic Air Flow," C. H. E. Warren, 7 p.m.

Thurs., Jan. 6th.—MAIN LECTURE : Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, Lecture to Young People, P. G. Masefield, 3 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Jan. 3rd.—ORDINARY GENERAL MEETING : 12, Great George Street, Westminster, London, S.W.1, " Valuations for the Purposes of the Town and Country Planning Act, 1954," 5.30 p.m.